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FURTHER STUDIES ON THE FAUNA OF NORTH AMERICAN HOT SPRINGS.

By Charles T. Brues.

(Continued from page 3 of cover.)

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[1] From the Entomological Laboratory, Harvard University.

Introduction.

The material contained in the present paper represents the third contribution of the writer dealing with the fauna of thermal springs in the Western United States. His first paper, published in 1924 was based upon observations and collections made in the Yellowstone National Park during the summer of 1923. In 1927 he was able to spend several months in the adjoining states of Utah, New Mexico, Nevada and California making a field study of a number of scattered hot springs, and obtaining collections of the insects and other types of animal life that occur in these springs. The results of these investigations were published in 1928.

Again during the summer of 1930 the same general region was revisited, including Yellowstone Park and parts of Idaho as well as Nevada and California. Nearly four months were spent in the field where observations were made and collections obtained in considerably more than one hundred separate thermal springs. The writer is deeply indebted to Harvard University for a grant from the Milton Fund for Research which was given him to aid in the continuance of these investigations. They involved a very considerable amount of travel on account of the scattered locations of the springs and frequently isolated positions that they occupy with reference to ordinary lines of travel. The writer traveled in his own car with a trailer (a distance of something over 14,000 miles) carrying necessary camping equipment and supplies. In this way it was usually possible although not always easy to get at least within walking distance of most of the springs, which numbered nearly one hundred and fifty. In most of these material was collected, although some proved unsuitable, usually on account of having been too much "improved" and thus rendered unfit for biological work. A few that we had hoped to visit proved to be too far from passable roads and others in the Death Valley region in California were omitted as the summer season is not suitable for travel there on account of the excessive heat.

As may be seen by reference to the accompanying map (Fig. 1) an extensive area has now been covered in this way and together with the thermal springs visited previously, we now have material collected at 154 localities. Each of these is indicated on the map, with a number; these numbers were given in sequence as we visited the springs and are the ones referred to later in the text. Numbers 35 to 154 are dealt with in the present paper.

As before, determinations of the hydrogen ion concentration of the

waters in which material was collected were made by the colorimetric method. A very compact kit made by the British Drug Houses, Ltd. of London was used. This contains a series of indicators, a supply of capillary tubes, pipette bulbs and small glass dishes, together with a series of standardized indicators in similar capillary tubes enclosed in light-tight envelopes to prevent fading. This, known as the B. D. H. Capillator proved very handy for use and highly satisfactory. The following indicators were used, with their ranges expressed in pH: bromphenol blue, 3.6–5.2; bromcresol purple, 5.2–6.8; phenol red, 6.0–8.4; thymol blue, 8.0–9.6. It is believed that the error cannot amount to more than 0.1 over the range between 7.2 and 9.6 which includes the great majority of the springs. Those above 9.6 and below 3.6 have not been differentiated, and quite a number fall into these classes.

The specific gravity of the water in every spring was also taken as a measure of its salinity. This was determined by a hydrometer reading to the fourth decimal place. By keeping the hydrometers scrupulously clean and taking the readings with careful reference to temperature it is believed that the specific gravity determinations are accurate to within 0.0004. All the determinations have been corrected to a uniform temperature of 15° Centigrade and thus give a general idea of the range of salinities to be found in the whole series of springs examined. On account of the great differences in salts present in the several springs the salinities are not biologically comparable as they are in the case of brackish waters which represent mainly dilutions of sea-water. As will be mentioned later the salinities fall mainly within a rather narrow range.

For recording the temperatures of water where collections were made thermometers reading to tenths of a degree Centigrade were used, previously calibrated to insure their accuracy.

The writer is indebted to several members of his family for assistance in collecting material and recording data. My wife spent much time in planning and arranging our itinerary and also made extensive collections of grasses associated with the hot springs. Determinations of the temperatures, specific gravity and hydrogen ion concentration of the waters were made in great part by my daughter, Alice M. Brues who also accompanied me during the entire trip. During a part of the time while my son Dr. Austin M. Brues and his wife were with us these data were taken and recorded by them. Without the interest and coöperation of these companions it would have been quite im-

possible to carry out such an extensive program in a region which presents so many difficulties to travel.

Much of the insect material obtained has been studied and identified by the writer but he is indebted to several other persons for assistance as mentioned in the more detailed account that follows. All of the beetles were determined by Mr. C. A. Frost who secured help from Mr. H. C. Fall and Mr. F. E. Winters. Mr. W. J. Clench and Mr. Arthur Loveridge, both of the Museum of Comparative Zoology, kindly determined the molluscs and amphibians respectively, while the identifications of the tadpoles were made by Dr. G. K. Noble of the American Museum of Natural History. The ostracod crustaceans were examined by C. H. Blake of the Massachusetts Institute of Technology and the fishes by Dr. Carl L. Hubbs of the University of Michigan. The series of Acarina were identified by Dr. Ruth Marshall of Rockford College. On account of the miscellaneous nature of the collections their identification has not been easy and the writer appreciates very keenly the inroads he has made upon the time of those who have aided him in this way.

Descriptive List of Hot Springs Studied.

These are listed and numbered serially in the order in which we visited them. In order to avoid any duplication of numbers or confusion in connection with my previous account (Brues '28), the present numbers begin with No. 35 as there are 34 springs described in the first paper. (See Fig. 1.)

No. 35. Thermopolis, Wyoming. Along the eastern bank of the Big Horn River close to the town of Thermopolis is a group of hot springs which have built up an extensive deposit of calcareous tufa that extends for a distance of about half a mile with a width of from 100 to 300 feet, overlooking the river. One very large spring at the southern end of the group furnishes water for a bath and sanitarium, but there is an extensive overflow from it and several smaller springs further down the river where our collecting was done. The springs are in a State Park as they were deeded many years ago to the State of Wyoming by the far-sighted old Indian Chief Washakie, with the provision that one-quarter of their flow should be set aside for the use of the public without cost. This has curbed to a great extent the exploitation of the springs by promoters of hot-water cures and sanatoria. The specific gravity of the water in the largest spring is 1.0056 and pH 7.9. As may be seen from the following analysis,

there is a considerable amount of calcium carbonate and much less silica.

Potassium chloride	175.60
Sodium chloride	449.20
Sodium sulphate	449.20
Magnesium sulphate	259.10
Calcium sulphate	225.60
Calcium carbonate	693.70
Ferric oxide & alumina	3.90
Silica (SiO_2)	85.50
Total parts per million	2,226.00

No. 36. Washakie, Wyoming. This is located in the valley of the Little Wind River, about one and one-half miles west of Washakie. The basin of the spring is several hundred feet across, filled with water holding much fine material in suspension that causes a very noticeable bluish or yellowish opalescence when viewed from the shore. The pool is practically at the level of the surrounding semi-desert country and is surrounded by very little vegetation. It is used for a swimming pool by the Indians of the reservation in which it lies and is provided with a large bath house, but the shores have not otherwise been disturbed. The specific gravity of the water is 1.0052 and pH 7.8.

Nos. 37–42. West Thumb, Yellowstone National Park. These six springs are all close together, near the Ranger Station, but as they differ considerably both in the specific gravity and hydrogen ion concentration of the water, have been listed separately. No. 37 is just southwest of the pink mud geysers or "Paint Pots"; No. 38, just southeast of the Paint Pots, and the three following are successively to the northward of No. 38. The first three hold a good deal of clay in suspension, with little or no overflow, while the others are clear and flow eastward over and through the porous calcareous tufa which they are depositing. Following is the specific gravity and hydrogen ion concentration of the six springs.

	Specific Gravity	pH
No. 37	1.0056	8.9
No. 38	1.0025	6.8
No. 39	1.0039	6.3
No. 40	1.0058	7.3
No. 41	1.0045	8.4
No. 42	1.0046	7.1

No. 43. West Thumb, Yellowstone National Park. This is also near the shore of Yellowstone Lake, about three-quarters of a mile north of the previous group, its overflow running down a gentle slope to the edge of the lake. The specific gravity of the water is 1.0023 and its reaction quite strongly alkaline (pH 9.0).

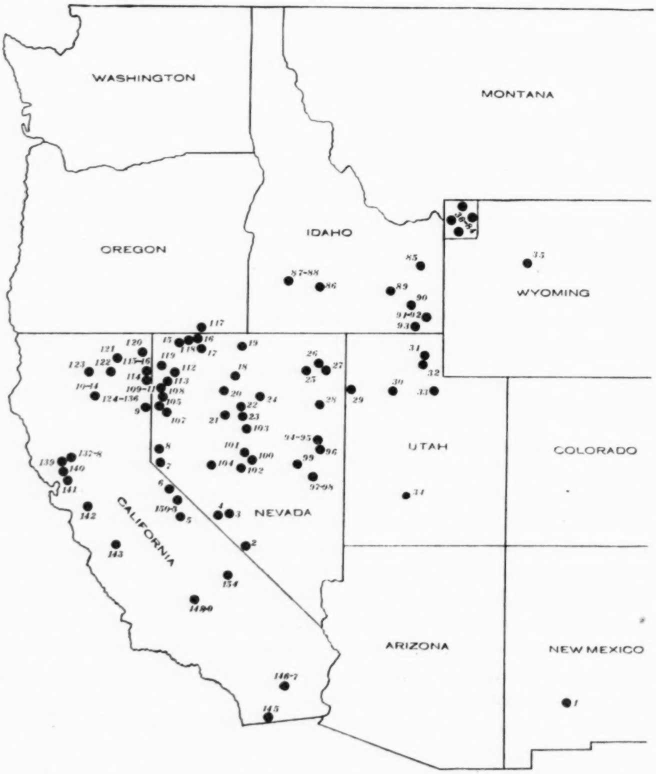

FIGURE 1. Outline map, showing geographical location of the hot springs in which material was collected. Each spring, or group of springs is indicated by a black spot.

No. 44. Lewis Lake, Yellowstone National Park. About twelve miles south of the West Thumb Station the road passes close to the edge of Lewis Lake and from this point, one half mile southwestward along the lake shore is an extensive flat swampy area fed by a hot spring, lying barely below the outlet to the lake. Here there are a number of pools and warm overflows with much vegetation in which we obtained a good deal of material. The specific gravity of the water is 1.0023 and its reaction only moderately alkaline (pH 7.8). There is little mineral deposit about this spring except a fine clayey, pale-colored mud.

No. 45. Norris Geyser Basin, Yellowstone National Park. This spring lies between the road and the Gibbon River opposite Roaring Mountain and not far north of the Norris Station. The water arises in a meadow area at a number of places and furnished good collecting at varying temperatures. The specific gravity of the water is 1.0040 and pH 7.9.

No. 46*a* and 46*b*. Bijah Spring, Yellowstone National Park. This locality is a short distance (1.6 miles) south of the previous one, where several springs emerge in a meadow within a distance of about 50 feet from one another. In spite of the proximity there is a difference in the specific gravity of two of these springs in which we obtained material so they have been listed separately (46a, 1.0039 and 46b, 1.0036) although the pH, 6.5, is the same in both. The temperature of these springs varies from 34.3° to 43.5°, and to judge from the absence of odor in the water the rather acid reaction is probably due to carbon dioxide.

No. 47. Indian Pond, Yellowstone National Park. Although this pond is evidently supplied in part by thermal water, its temperature at the time of our visit (July 27) was only 17.1° C. (62.8° Fahr.) along the shore and the specific gravity only 1.0001. It is really therefore practically an ordinary fresh-water pond. Some material was obtained here for comparison with that collected elsewhere in this vicinity.

Nos. 48 and 49. Beach Springs, Yellowstone National Park. The group of springs bearing this name is practically at the extreme northeastern corner of Yellowstone Lake, situated close to the lake shore. They are separated into two groups by a slight rise, the northernmost one (No. 48) containing water of a specific gravity of 1.0028 and pH of 6.5. The water is slightly muddy with a grayish clay border and a maximum temperature of about 34°. The water in

the southern group of three more or less connected pools is less acid, with a pH of 7.2 and with a higher specific gravity (1.0051). The water is slightly warmer, ranging from 38.5° to 40°.

No. 50. Mary Bay, Yellowstone National Park. This spring is not far south of the preceding ones, also near the shore, but it has a large flow which finds its way to the lake as a small stream. The water is very hot at its source, with a specific gravity of 1.0022 and pH of 7.3, and as it cools contains much green vegetation.

No. 51. Mary Bay, Yellowstone National Park. These springs are near the lake shore just north of the base of Steamboat Point which rises sharply above them. They lie in a grassy slope well above the lake and are surrounded by soft, muddy, and crusty seepage areas which disappear at the gravelly beach next to the margin of the lake. The water is moderately saline, with a specific gravity of 1.0038.

Nos. 52–56. Turbid Lake, Yellowstone National Park. These springs are near the eastern shore of Turbid Lake, No. 52 between the East Entrance Road and a small stream that enters the lake not far north of the road; Nos. 53, 54 and 55 follow one another as one passes northward along the eastern shore, and No. 56 is near the northern corner of the lake. They differ among themselves greatly in salinity and hydrogen ion concentration in spite of their similar positions with reference to the lake shore. Nos. 52 and 53 are highly acid (pH 3.6) with specific gravities of 1.0025 and 1.0034 respectively while the others are much more alkaline (No. 54, pH 8.6; sp. gr. 1.0025; No. 55, pH 7.3; sp. gr. 1.0066; No. 56, pH 7.2; sp. gr. 1.0040).

No. 57. Tower Junction, Yellowstone National Park. Between Tower Falls and the junction with the road from Mammoth is a large spring to the west of the road which arises from the slope of a hill and supplies sufficient water to form several small streamlets. This water is conveyed for a short distance through a pipe, but both above and below this there is both running water and several small marshy areas which furnished good collecting. The temperature of the water is only about 45° at the hottest part, but on account of the good flow it cools rather slowly as it runs off. There is a smell of hydrogen sulphide and the pH is rather low (7.0), with a specific gravity of 1.0057.

No. 58. Whirligig Geyser, Yellowstone National Park. The water in the run-off from this geyser is extremely acid in reaction, pH below 3.6, and is moderately saline with a specific gravity of 1.0051. As

with all geyser overflows the amount of water varies greatly and its temperature fluctuates in conformity with the activity of the geyser. Such locations are therefore not generally favorable for the occurrence of animal life of any kind.

No. 59. Near Minute Man, Yellowstone National Park. This is a warm flow at a culvert along the road in the Norris Geyser Basin about 100 yards south of the Minute Man Geyser. The water here is also highly acid with a pH of less than 3.6 which was the lower limit of the indicators we had with us. The specific gravity is 1.0026 and the temperature quite low, barely 25° in the warmest parts.

No. 60. Angel Terrace, Yellowstone National Park. This and the two following locations are near Mammoth Hot Springs. The first includes a spring (60a) just north of the once beautiful and well-watered Angel Terrace which was practically extinct at the time of our visit, and another (60b) known as the New Highland Terrace which lies directly southwest of 60a. The water here has a pH of 8.3 and specific gravity of 1.0040. We were disappointed to find that Bath Lake, a pond in which we had obtained much interesting material on the occasion of a previous visit in 1923 remains only as a dry depression, completely devoid of water.

No. 61. Soda Spring, Yellowstone National Park. Two springs within a few feet of each other are of quite different temperatures, one at 29.0°, known as Soda Spring and the other containing water as high as 39.2°. The composition of this spring is shown by the following analysis which is posted there by the Park authorities. The water is quite acid (pH 6.9) and moderately saline (specific gravity 1.0048).

Potassium chloride	93
Sodium chloride	182
Sodium sulphate	220
Magnesium sulphate	328
Calcium sulphate	392
Calcium carbonate (acid)	1,113
Ferric carbonate (acid)	34
Silica (SiO_2)	78
Total parts per million	2,440

No. 62. White Elephant, Yellowstone National Park. This is a hot pool at the western edge of the "Elephant," a mound of travertine still in slow process of deposition near the southern edge of the

active springs at Mammoth Hot Springs. The water is hot, over 50° at the center, but cools about the edge. The pH is 6.9 and the specific gravity 1.0058.

Nos. 63 and 64. Amphitheatre Springs, Yellowstone National Park. This is a group of pools in a depression about a mile to the east of the main road about five miles north of Norris Junction and a little more than a mile south of the Obsidian Cliff. There are a number of rather large pools which lie between two wooded hills and their overflows combine to form a small stream. The temperature of the water is nowhere very high, ranging between 30° and 40°. The water is highly acid (pH 3.6 or less) and the specific gravity 1.0043 and 1.0034 respectively.

Nos. 65–67. Firehole River, Yellowstone National Park. These springs are along the Firehole River near Old Faithful, opposite the lodge cottages. No. 65 is a small spring containing very little water of pH 8.3, of low temperature (32°–34°) but it yielded a good deal of material. No. 66 is a very hot pool, 100 feet east of No. 65, with the overflow filled with yellow and olive brown algæ. The pH of the water is 8.9 and its salinity rather low (1.0023). No. 67 is a fast flowing streamlet again 100 feet east of the last one, pH 8.2 and specific gravity somewhat higher (1.0044). It contained numerous insects and crustaceans.

No. 68. This and the six following springs are in the Shoshone Geyser Basin which lies about seven and one-half miles in a straight line south of Old Faithful at the extreme western extremity of Shoshone Lake. This area is accessible only by a trail about twelve miles in length and is little visited as there are no accommodations there for tourists. However, through the kindness of the park authorities at Old Faithful we were allowed the use of a ranger cabin that is maintained near the shore of the lake and were able to secure saddle and pack horses for the trip. The cabin is just a few yards west of the southernmost springs of the Yellow Crater group. This is a particularly good region for zoological work as it affords a great variety of springs in their original condition, all grouped on the slopes that rise to the west from the bank of Shoshone Creek at this place. Many of these are boiling or extremely hot, but the overflows and other cooler pools proved to be good for collecting. No. 68 is the run-off from a hot pool about 100 yards northeast of the cabin. The pool lies on a slight rise due to the deposits it has laid down and the overflow is in part rather shallow. This is a strongly alkaline spring with pH of

9.4 and a specific gravity of 1.0040. Collecting was done here in water as high as 41.6°–41.8°. This spring is evidently No. 11 of the Yellow Crater group described in Hayden's report for 1878 (vol. 2, p. 288).

No. 69. Shoshone Geyser Basin, Yellowstone National Park. This pool is about fifty yards east of the previous one and lies at a lower level, with a soft clay margin. It is quite shallow, with little vegetation and the temperature of the water does not rise above 32° at any place. It was inhabited by beetles, tadpoles and leeches at the time of our visit, but collecting was difficult on account of the very soft muddy bottom and surroundings. The water is less saline and less alkaline than in the previous spring, with a specific gravity of 1.0036 and pH of 8.2.

No. 70. This is a large pool less than 100 yards south and slightly west of the cabin on somewhat higher ground. It has a temperature of about 31.5° and is apparently devoid of algæ. It is moderately saline, specific gravity 1.0042 and rather strongly alkaline, pH 9.0.

No. 71. Near the west shore of Shoshone Creek about a quarter of a mile south of the previously mentioned springs is a large actively flowing spring which runs down into the creek. The overflow widens out considerably in a very irregular way due to the deposit which it lays down along the lines of flow. It thus spreads out more or less fan-shaped to the edge of the creek where it empties almost opposite to a small very active geyser known as the Minute Man that plays from an elevation near the east bank of the creek. The overflows contain a good growth of algæ in water of a specific gravity of 1.0046 and pH 8.8.

No. 72. This location is next below No. 71 also on the west side of the stream a distance of about 100 yards. The spring lies near the edge of a wooded area which approaches Shoshone Creek at this point. There is no direct overflow and the specific gravity of the water is rather high (1.0062) and the reaction moderately acid (pH 7.7).

No. 73. This is east and slightly north of the cabin at a distance of about 60 yards, and consists of a small spring and extensive seepage overflow that drains northeastward to Shoshone Creek. The water in this spring is very different from the others in this group, having an extremely acid reaction (pH 3.6 −) and a moderate salinity of 1.0058.

No. 74. This location includes several small springs near together on the east shore of Shoshone Creek almost directly east of the cabin.

They drain into the creek by a small streamlet with grassy sides and soft, pale clayey bottom. The water is quite acid (pH 6.4) and its specific gravity is 1.0047.

There are numerous small geysers in the Shoshone Geyser Basin and many highly varied and beautiful boiling or extremely hot springs, some of them of great size and depth. The majority are of course not suitable for the occurrence of animal life on account of their high temperature, intermittent overflow or rapidly changing run-off channels.

No. 75. Three Sisters, Yellowstone National Park. This is an overflow about 100 yards northwest of the Three Sisters Springs which are about half a mile west of Old Faithful Geyser. This overflow is quite shallow, extending for a considerable distance as a number of streamlets over the sloping formation close to the road leading to the Black Sand Basin. The water is highly alkaline, with a pH of 9.1 and specific gravity of 1.0046.

No. 76. Sunset Lake, Yellowstone National Park. This is the overflow from Sunset Lake which finds its way into Iron Creek near the center of the Black Sand Basin about one and one-half miles west of Old Faithful Geyser. The water is apparently quite similar to that of the previous spring; pH 9.0, specific gravity 1.0043.

No. 77. Lower Geyser Basin, Yellowstone National Park. This spring is another three-quarters of a mile further along the Black Sand road as it turns northeastward beyond Sunset Lake, and lies next to this road at the point where a branch road leads to the White Pyramid Geyser Cone. It forms a brownish pool surrounded by low vegetation, the water highly alkaline (pH 9.5) and of moderate salinity (1.0056).

No. 78. Biscuit Basin, Yellowstone National Park. This is an overflow which finds its way into the Firehole River just north of the foot-bridge which leads to Biscuit Basin from the automobile road about two miles north of Old Faithful. Like the previous springs the water is highly alkaline (pH 9.6 +) with a specific gravity of 1.0040.

No. 79. Sprite Pool, Yellowstone National Park. This is a very large overflow of varying temperature which extends over a considerable area. It has laid down a large amount of deposit over which the hot waters pour in great volume. They contain quantities of yellowish and greenish algæ and deposition is evidently proceeding at a rapid rate. From its size, extensive flow and large amount of deposited material, this spring gives evidence of considerable age and uniform

flow. The water has a specific gravity of 1.0039 and pH of 8.9. Here we found numerous specimens of *Thermacarus nevadensis*, the first taken in 1930, and were able to establish its occurrence in the Park.

No. 80. Firehole Spring, Yellowstone National Park. This is an extremely hot pool which lies at the end of a branch road that leads off eastward from the southern edge of the Lower Geyser basin toward Firehole Lake. In the overflow some collections were made in water of pH 8.2, specific gravity 1.0046.

No. 81. Tangle Creek, Yellowstone National Park. This is the overflow from Hot Lake near the eastern margin of the Lower Geyser Basin. The water runs rapidly along a well-defined stream-bed, east of and more or less parallel with the road that leads from the Great Fountain Geyser toward Hot Lake. The temperature drops gradually as one passes down stream and was near 33° along the stretch where we made our collections. The water is heavily charged with silica which is deposited along the course of the stream as a smooth black coating, which gives a peculiar appearance to the surface of immersed objects, as though they had been dipped in a black varnish. Stones and other loose objects are cemented to the bed of this stream by the deposit. We had visited the same place in 1923 and found the same conditions prevailing in 1930, seven years later. The deposition must be very rapid, as on the former occasion we found a piece of burlap in the water which had been completely covered with the black silica as though coated with tar. The characteristic insect of this location is *Ambrysus heidemanni*, found abundantly in both years. The water showed a specific gravity of 1.0037 and pH of 8.4.

Nos. 82 and 83. Near Ink Well, Yellowstone National Park. These are both near the Ink Well which lies close to a foot-bridge across the Firehole River about a mile north of Old Faithful. No. 82 is on the west side of the river in a rather low swampy place; the water is highly alkaline (pH 9.6 +) with a specific gravity of 1.0038. No. 83 is a very extensive flow arising south of the foot-bridge on a sinter elevation whence it flows northward, expanding irregularly to form numerous depressions more or less clogged with algæ and depositing material. It yielded a considerable amount of material. The water is rather strongly alkaline (pH 9.1); specific gravity 1.0039.

No. 84. Near Spasmodic Geyser, Yellowstone National Park. This spring is quite similar to the last with a large overflow that runs off in a southerly direction from its point of origin south and

slightly west of the Spasmodic Geyser. It is well supplied with algæ and supports a quite considerable fauna in strongly alkaline water (pH 9.3) with a specific gravity of 1.0032.

No. 85. Heise, Idaho. These springs arise on the northeastern bank of the Snake River at the Heise Hotel and Bath Houses, at a distance of twenty miles almost directly northeast of Idaho Falls, although the distance by road is between 45 and 50 miles from that city. The springs arise on a promontory overlooking the river and about forty feet above it. There was formerly a series of hot baths next to the springs, but these have been abandoned and the water is now piped for a distance of several hundred feet to the hotel. Our collecting was done in the seepages directly along the side of the elevation on which the springs emerge and in small pools derived from the leaky pipe which carries the water. The water is heavily charged with salts, showing a specific gravity of 1.0087, but unfortunately our record of the pH has been mislaid. The proprietor of the hotel informed us that the corrosive action of the water on iron or galvanized piping is so great that it requires very frequent replacement. The swampy slope watered by the springs is muddy, without much evidence of mineral deposits and supports a good deal of vegetation, mainly the alkali-grass, Distichlis.

No. 86. White Arrow Sanitorium, Blanche, Idaho. This spring arises in Gooding County, about nine miles north of Bliss, a station on the Oregon Short line and also on the transcontinental highway "U. S. 30," about 100 miles east of Boise. From Bliss it may be reached over a good secondary road, although the approach from the east is barely more than possible for an automobile. The spring has a large flow which forms a stream that flows for a distance of several hundred yards to a flat area where it disappears and at several places along its course part of the water is led off into ditches for irrigation. Collecting at a number of places along the stream yielded a fairly varied series of aquatic insects at temperatures between 30° and 41°. The water is rather saline, with a specific gravity of 1.0060, and only moderately alkaline (pH 8.6).

Nos. 87 and 88. Mountain Home, Idaho. Like the preceding locality, Mountain Home is also on the Oregon Short Line and "U. S. 30", about 50 miles west of Bliss and an equal distance east of Boise on the highway. The springs are about eight miles northeast of the town and are easily reached over a good secondary road. They arise at an altitude of 3700 feet through lava about a mile south of the

rhyolite of Mount Bennett on the sloping edge of a large flat area close to high lava cliffs that rise up about 1,000 feet to the northeast. The five springs form two groups each giving rise to a small stream. After about 50 yards the two unite and pursue a winding course through the sage-brush flat finally finding their way into Bennett Creek and thence to the Snake River. The springs vary in temperature from 40° to 75° and although some collecting could be done close to the springs, the temperature of the stream, whose flow is said to be about 120 cubic feet per minute, is not cool enough for animal life until it has flowed out for a considerable distance. The slope about the springs is grassy and more or less marshy, although the stream below cuts its way quite sharply with steep sides and little vegetation appears aside from the desert vegetation which, as is generally the case next to water of any kind, grows with noticeable luxuriance. The combined flow of two of the springs, which are of lower temperature than the others we have listed as No. 87, with highly alkaline (pH 9.6) water of but little salinity (1.0029). The flow of all combined after the flows from both groups of springs have united forms No. 88, having a higher salinity (1.0036), but the same hydrogen ion concentration. No doubt the greater salinity of the stream is due to the greater solvent power of the hotter water in the second group of three springs.

No. 89. Indian Springs, Idaho. These large springs are reached by a short side road which leaves the main highway (U. S. 30) just southwest of American Falls, or about 17 miles west of Pocatello, Idaho. They have been transformed into a resort with large bathing pool, but are nevertheless still highly interesting. The springs arise at the edge of a hill that borders the northern edge of an extensive flat area. One of these has been led from its origin in a small gully to the west of the buildings into a warm pool in which the proprietor maintains a colony of goldfish. This pool and the water between it and the origin of the spring furnished a good series of specimens. Further eastward, perhaps 100 yards distant we made a second series of collections in the rocky bed of the stream which is derived partly from the spring that supplies the bath house and from others that occur along the hill slope at that point. These latter springs also supplied material. The temperature of the water is moderate, between 32° and 33°, but it is well mineralized with a specific gravity of 1.0031. It is but slightly alkaline; pH 8.4.

No. 90. Lava Hot Springs, Idaho. This little town is on the

Partneuf River twelve miles east of McCammon which is on the Oregon Short Line 23 miles south of Pocatello. It may be reached by a road ten miles long that leaves the highway (U. S. 91) at a point two miles south of McCammon. Here a number of hot springs issue from the bank of the river. Some of these supply a large public natatorium, but there are others along the river just below a large park, accessible by a steep and rather precarious path that descends about 100 feet to the level of the river. Hot water issues at several places along the bank of the river and in the bed of the stream at the shore. The hot water thus mingles with the cold stream water so that it is difficult to determine temperatures, except where pools of constant temperature are formed. As happens under such conditions the hot water tends to flow over the surface and crayfish that were living on the bottom were killed by heat in removing them through the supernatant hot water for preservation. The water is quite saline, with a specific gravity of 1.0053.

No. 91. Cleveland, Idaho. This locality is southeast of the last one and northeast of Preston, Idaho from which it is accessible by road, a distance of twenty-five miles. There are about six springs in a group in a pasture just south of the road and next to the village store. The ground slopes at first slightly and then steeply to the south where it borders on a broad flat area along the edge of Cottonwood Creek which flows eastward and almost immediately enters Bear River which flows south at this point. The springs form large shallow pools with grassy borders, separated by marshy land near the road and by more dense, brushy vegetation below on the steep lower slope. The water is used for irrigation and for watering stock although it is rather saline (pH 7.5). These pools support a varied fauna and we secured much material here at temperatures ranging from 28° to 42°.

No. 92. Cleveland, Idaho. This location is very near to the previous one, on the other side of the Bear River near the summit of a steep slope that rises above the river. The spring arises near the road that extends along the eastern side of the river and fully 100 feet above the stream, so that looking across one may see the other springs and below them the clover fields that they irrigate. This spring has a quite extensive flow and is rapidly depositing a calcareous material on the side of the hill on its descent to the river. Undoubtedly this spring has built up the elevation from which it now emerges as the surrounding soil has the characteristic appearance of

hot springs deposits. The occurrence of the thermophilous mite, Thermacarus, here, also suggests that it is a permanent spring of considerable age.

No. 93. Preston, Idaho. This spring is about four miles northwest of the town, on the western side of the Bear River, only a few hundred feet from the shore. It has a rather large flow, most of which is led to a bath-house, but the remainder flows out into a clayey, muddy flat covered with sparse, low vegetation, consisting mainly of alkali grass (Distichlis). The water issues from near the base of a slope that rises just to the west of the road and after passing under the road spreads out, flowing northward into the marsh just described where it is gradually absorbed without flowing into the nearby river. The water emits a vile, more or less sulphurous odor which permeates also the surrounding whitish mud and soil. The water which is very highly saline, with a specific gravity of 1.0150 is slightly alkaline (pH 8.0), and was found to contain numerous larvæ of Ephydra. In relation to the springs at Cleveland, also on the Bear River, the present location is about 18 miles southwest in a straight line.

Nos. 94 and 95. Cherry Creek, Nevada. This may be reached from the new transcontinental highway U. S. 50. At the town of Schelbourne about 100 miles south of Wendover, Utah, a secondary road leads northwestward 16 miles to the town of Cherry Creek and the springs are a couple of miles south of the town. They may be approached also from the south from Ely over a secondary road, a distance of about 50 miles. These springs are on a ranch which sets on the slope of hills that rise to the west, surrounded by sage-brush vegetation. The water of the main spring (No. 95) issues in large quantity from a crater-like depression in a bare mound of deposit and is used for irrigation and domestic purposes. Several hundred feet further south is a smaller flow (No. 94) surrounded by sparse vegetation which disappears after flowing down a gully for a short distance. The water of both springs is very hot (above 55°) where it emerges, but cools as it runs off down the slope. Both springs have a pH of 8.4, but the specific gravity of No. 94 is less (1.0038) than that of No. 95 which is 1.0043.

No. 96. Monte Neva, Nevada. This large spring is about 15 miles north of Ely, Nevada on the secondary road to Cherry Creek which lies west of the main highway (U. S. 50) that leads from Ely to Wendover, Utah. There is a copious flow of very clear, hot water that has been partially impounded into a large pool from which it is led off

through a ditch to be cooled and used in a well-appointed nearby bath-house, swimming pool and hotel. The water is depositing large quantities of mineral matter as it cools and there is considerable seepage from the pool which is elevated above the surrounding land, undoubtedly on material deposited by the spring. Along the ditch much of the deposit is forming at the surface of the water along the edges, in liver-like outgrowths with lobate or scalloped edges, showing noticeable bands of ferruginous red color. The water is not highly saline, showing a specific gravity of 1.0038 and is slightly alkaline with a pH of 8.4.

Nos. 97 and 98. Sunnyside, Nevada. This locality is on a secondary road that leaves the main Ely-Tonopah highway 28 miles from Ely and leads southward to the Sunnyside Ranch some 45 miles further. The springs are several miles beyond the ranch, and on the way the road crosses a warm stream formed by the overflow from the spring. No. 97 is the stream near the bridge at the crossing. Here the temperature of the water is 30.8° and the pH 9.3. The spring itself is about a mile further south and may be easily located by two isolated buttes of Silurian age that rise near it. It flows a very large volume of water at a temperature near 34°, which forms a large tule-bordered pool with a considerable extension to the westward. The outlet is to the east from whence the previously mentioned spring flows north as a good sized stream. The water at its source (No. 9) is more saline, with a specific gravity of 1.0042 and less strongly alkaline pH 8.3. This is undoubtedly a very old spring, for although it is not now depositing mineral matter in any quantity, the surrounding sage-brush plainly shows evidence of extensive hot-springs formations. In places it is cut by gullies or shows mounds that rise above the level of the plain over an area of several square miles, often to a height of forty feet.

No. 99. Duckwater, Nevada. This location may be reached in two ways from the transcontinental highway "U. S. 50" by traveling south about 40 miles. One road leads off about 20 miles west of Ely going through Hamilton an old mining town now nearly deserted; the two meet at Duckwater which is just south of the spring. Both roads are very poor and rough and the one through Hamilton has a number of steep grades. Probably the other and shorter road over which we returned is the better. This spring seems to issue from a fissure and has a rather large flow of clear water, having a specific gravity of 1.0032 and pH of 8.0, and a temperature of about 32° at its source.

It does not appear to be actively depositing mineral matter, but is raised above the surrounding land on deposits evidently laid down in the past. The water flows out as a small winding stream that soon disappears in a marshy pasture. The stream contains a good growth of algæ, a number of insects and here we found the remarkable new fish, *Crenichthys nevadæ*. To judge from the large flow, evidence of extensive formations and presence of this peculiar fish, this spring is undoubtedly a very ancient one.

No. 100. Antelope Valley, Nevada. This spring is reached by a road that leaves the main Eureka-Austin highway about 25 miles west of Eureka. This little used road leads south and the spring is reached after traveling eleven miles. This location is in a sloping grassy valley with a seep of cold, potable water and a short distance further down is a large hot spring emitting a copious flow of water at about 60°. It is led off through a ditch and fallen-down building which was probably at one time a bath-house. Near here are some sulphur fumaroles. The timbers of the house were blackened by the sulphur fumes. As the water flows down along a winding course through the sage brush and widens out into a grassy marshy area we made extensive collections both in the marsh and in the eddies of the swift stream. Near its source, the water is depositing mineral matter in considerable amounts, but further down only a whitish clayey mud. The water has a specific gravity of 1.0032 and strongly alkaline reaction of pH 9.1.

No. 101. Birch Creek Ranch. This is on a secondary road that leaves the main Eureka-Austin highway twelve miles east of Austin, Nevada. The Birch Creek Ranch is only two or three miles south on this road and from the ranch a trip of two or three miles to the east across a wide valley, over an almost impassible road leads to the spring. This arises on the lowest slope of the mountains that lie to the east and flows for a short distance to two deserted and dilapidated "bath-houses" after which it spreads out into a marshy area. There is some mineral deposit about and below the spring, but little more than fine clay seems to be forming at the present time. The water has a specific gravity of 1.0032 and pH of 7.3.

No. 102. Darroughs Hot Springs, Nevada. This locality is about fifty miles south of Austin, Nevada from which it can be reached by secondary roads. One of these extends directly south from Austin, and the other and better one is the road already mentioned (Spring No. 101) that leads south from the highway 12 miles east of Austin.

The springs lie in the Big Smoky Valley at the foot of the Toyabe Range which rises directly to the west. There are several springs in this group, the largest actively boiling and another emitting a quantity of steam which is used for steaming hams by the ranch owners. The springs cover an area of several acres; one to the northwest and at a higher level than the hottest ones furnished good collecting. There is some calacareous deposit in the vicinity of the present outlets and generally within a radius of several hundred feet. The specific gravity of the water is 1.0038 and the pH 7.3 in the spring where the collecting was done. An analysis of the water from the boiling spring according to Meinzer ('17), p. 89 and p. 154, is given below:

CONSTITUENTS IN PARTS PER MILLION

Silica (SiO_2)	88
Calcium	13
Magnesium	3
Sodium and Potassium	80
Carbonates (Co_3)	31
Bicarbonates (HCO_3)	102
Sulphates (SO_4)	60
Chlorine	15
Total dissolved solids	392

No. 103. Cortez, Nevada. This spring is forty-five miles northeast of Austin, Nevada and may be reached over a secondary road that extends northward from the main highway about three miles east of Austin. This road leaves the highway in the mountains just east of Austin and descends to Grass Valley, proceeding northward in the floor of the valley past the ranch where the springs are located. Here an actively flowing spring issues from a calcareous mound whence it is led through a swimming pool and later used for irrigation. The spring is on the east side of Grass Valley and the overflow forms a large green area below it, traversed by tule-bordered ditches. The water issues at a temperature of over 70° and it is still very warm when it reaches the meadow. The water is depositing large quantities of calcareous material near the spring, but itself is not highly mineralized, showing a specific gravity of 1.0041 and mildly alkaline reaction (pH 8.5). We secured interesting and extensive collections here.

No. 104. Monte Christo, Nevada. This locality is rather difficult of access over a road which extends south of the transcontinental highway 83 miles west of Austin and 97 miles east of Reno, Nevada.

This side road is passable, but difficult, winding through mountains for about 30 miles to the spring which is at the eastern edge of a large alkali flat. It is possible to drive westward across this flat and join a road at Deadhorse Well which leads through Rawhide and thence north to the highway, which we did on returning. This is a large spring with extensive flow, the overflow forming several large pools and a marshy area. It arises near the southern tip of the Sand Springs Range, presumably through lava rock as the road is through lava for some miles to the north. There is little mineral deposit from the spring which issues at a level barely above the alkali flat. The water has a specific gravity of 1.0052 and pH of 8.7.

Nos. 105, 106 and 107. Pyramid Lake, Nevada. Pyramid Lake lies in western Nevada, north and slightly east of Reno, Nevada. About fifty miles over a very good secondary road one can drive to the Post Office of Pyramid on the western shore of the lake. The lake receives its name from a large hot-spring tufa cone that rises high above its waters near the eastern shore. At the present time the flow of the water from the "pyramid" is much reduced but there are a few tiny geyser-like outlets not far above the surface of the lake and others at or just below the surface. As the sides are very steep the overflows pass quickly into the lake and we found no opportunity to do any collecting here. However, at the northern extremity of the lake there are a number of small springs issuing close to the shore, near a series of tufa-covered rocky prominences, The Pinnacles, that line the shore. These springs are all of small size and very limited flow, but in several of these we were able to collect a considerable amount of material. They vary but little in salinity, and not greatly in pH, all being moderately alkaline.

	Specific Gravity	pH
No. 105	1.0064	8.0
No. 106a	—	8.4
No. 106b	—	8.4
No. 107	1.0074	8.4

The water of Pyramid Lake had a specific gravity of 1.0062 at the time we were there, but in 1877 was stated by Hague and Emmons ('77) to be much lower (1.0027). At the present time the lake is receiving less water than normally due to an artificial diversion of the Truckee River, its level has dropped noticeably, and no doubt, the future will see it unfit to support the abundant fish now found there as its salinity is increased through evaporation.

No. 108. Gerlach Hot Springs, Gerlach, Nevada. Gerlach lies north and slightly east of the northern end of Pyramid Lake about 30 miles in a straight line. It may be reached by a road said to be reasonably good that extends northward from Pyramid passing west of the Lake Range, thence across the southwest arm of the Black Rock Desert and then north along the edge of the desert. We ourselves followed a road that crosses the Lake Range at the northeast corner of Pyramid Lake and thence northward along the southeast arm of the desert. This proved to be only a sheep trail for some 20 miles after crossing the mountains, but was finally negotiated after a very difficult and arduous day's travel. The springs form a group of three pools about half a mile west of the town of Gerlach, one of which is some twenty feet in diameter filled with water near the boiling point. The overflow waters a green meadow of considerable size and in the partially cooled run-off considerable material was collected. The water is quite strongly saline with a specific gravity of 1.0061 and rather acid reaction (pH 7.5). There is practically no hard mineral deposit about these springs although they are slightly above the level of the surrounding country due to clayey material which is also noticeable along the course of the overflows.

Nos. 109, 110, and 111. Sixteen miles northwest of Gerlach, Nevada. Proceeding northward from Gerlach which lies at the extreme southern end of the Granite Range along the edge of the desert and thence west and north is a group of several large pools producing a large flow, sufficient to irrigate a good-sized ranch. They reach the surface in a low meadow bordering an alkali flat and about a mile east of the mountains of the Granite Range that rise rather steeply to the west. Of the three pools which we examined, one small one is extremely hot (about 75°) while the other two, one of which is perhaps 75 feet in diameter, are only warm (32.5° and 33.7°). The large pools are all surrounded by a luxurious fringe of tule rushes, next to the shore which rises sharply several feet above the water. This is evidently an ancient group of springs, possibly not all from the same source considering the great difference in temperature, as it seems probable that the supply of water in the large cooler pools must be in part derived from the adjacent mountains, especially as there are other cool or cold springs (*e. g.*, No. 113) further north along the eastern edge of the Granite Range, in essentially similar positions. The specific gravity and pH of these springs are as follows: No. 109, sp. gr. 1.0029, pH 8.5; No. 110, sp. gr. 1.0024, pH 8.3; No. 111, sp. gr. 1.0042, pH 8.7.

No. 112. Black Rock Desert, Nevada. Although we were unable to do any collecting in this spring it is so remarkable in appearance and location that it seems worth while to describe it briefly. It lies near the eastern edge of the completely barren Black Rock Desert about 40 miles northeast of Gerlach from which it may be reached by driving over the absolutely flat clayey floor of the desert to a point near the conspicuous, dark, rocky hill from which the desert derives its name. On account of the mirages it is difficult to estimate distance, or to be sure of the location of distant objects. The spring is a large pool of very hot water set near the base of some hills, whence it flows over a gentle slope to the plain that sets just above the level of the desert, to disappear in this area which is covered with a sparse growth of desert plants. The pool is about 50 feet in diameter, surrounded by a large area of highly luxuriant tule rushes which also surround the overflow and make the locality a most conspicuous and pleasing, verdant landmark. The pool is accessible where the very hot water issues at the upper, eastern edge, but the rushes and swampy soil make access to the cooler parts very difficult. So quickly is the water absorbed that no actual overflows could be found of sufficient size for collecting. The composition of the water is apparently quite similar to the springs just described northwest of Gerlach on the other side of the desert, with a specific gravity of 1.0046 and pH of 8.4.

No. 113. Soldier Meadows, Nevada. These springs are about 35 miles almost directly north of Gerlach, Nevada, very close to the road that leads to Soldier Meadows along the western side of the Black Rock Desert. The road here passes through a sparse growth of desert shrubs very little above the floor of the desert but at the eastern base of mountains that rise more than two thousand feet above it. Although of undoubted thermal nature the water is cool. It waters an area of perhaps an acre of alkali grass (Distichlis) with a mixture of some other low herbs and a portion that is covered with water is well populated by frogs and toads. The water has a specific gravity of 1.0007 and pH of 8.8.

No. 114. Hausen, California. These springs are at the south end of Surprise Valley at the southern end of Lower Lake, just over the California border and about twelve miles south of Eagleville. There is a large flow of warm water which supplies a small bath-house and serves to irrigate a large field. The springs are only moderately warm and our collecting was done at 36.2° in an extensive overflow that

forms a gulley near the several houses that compose the town. The water has a specific gravity of 1.0033 and pH of 7.5.

Nos. 115 and 116. Surprise Valley, California. Between Hausen and Eagleville there are a number of hot springs that issue from the gravel or boulders of the hillside between the road and the lake bed to the east. These form a series of irregular small rocky streams that serve to water small areas. Some are merely seepages, but others have considerable flows that run for distances of 100 yards or more. In most cases the water is only slightly warm but two were of sufficient size and hot enough to be of considerable interest and yielded an extensive series of specimens. The water is of moderate salinity, 1.0027 and 1.0035 and the pH 8.3 and 7.6 respectively for the two springs listed.

No. 117. Denio, Oregon. This is a group of several springs six and one-half miles south of Denio, Oregon which lies just over the state line in Nevada so that the springs are in the latter state. We visited these springs in 1927 (No. 16 at that time) and were surprised to find after a lapse of three years that they had greatly decreased in flow, especially the isolated spring about a quarter of a mile east of the others which was nearly dry although previously flowing actively. This may be temporary, as a lake just to the north previously filled with water was entirely dry. However, as the flow from these springs is very hot this does not seem entirely likely as they do not appear to have their origin in meteoric water. The water was still very hot (about 75°), but its specific gravity had increased from 1.0015 to 1.0024 and its pH had changed from 8.5 to 7.5. Possibly these springs are destined soon to become extinct and join some of their neighbors whose former presence is now indicated only by their fast weathering deposits dotted over this vast desert region.

No. 118. South of Denio, Oregon. This is a very large and extremely interesting hot spring which lies west of No. 117 about four miles. It may be reached by traveling south five and one-half miles from No. 117 and over a right hand road that leads northwest another four miles to the spring. We had almost reached this spring in 1927, but were forced to turn back to repair our engine. An enormous volume of water at about 52° issues here in a large pool surrounded by a grassy meadow from which a rapidly flowing stream some eight feet wide extends south and later eastward, first through the desert and later into land which it irrigates. The stream is filled with fleshy green algæ and we obtained an extensive collection. This is a very

active spring and although it has built up only a comparatively small amount of mineral deposit is undoubtedly of great age and permanence. The water has a salinity of 1.0030 and pH of 8.4. It arises well removed from any mountains, just west of the northern tip of the Pine Forest Mountains in an extensive flat area sparsely clothed with desert plants at an altitude of about 4,000 feet.

No. 119. Fish Springs, Nevada. These springs form one of the very few watering places along the distance of more than one hundred miles between Cedarville, California and Denio, Oregon. Although perhaps of thermal origin the water is cold and potable. The flow is small in amount and disappears in the arid soil within a quarter of a mile from its source. The spring and overflow support numerous aquatic insects and we secured a collection for comparison with others made in the hot springs of the same region. Fish Springs arise from the western slope of a low range of rocky hills. The water leaves no white deposit, but flows over black mud containing innumerable minute particles of opal evidently derived from opalized wood exposed on the slopes above.

No. 120a. Cedarville, California. Just east of Cedarville a distance of five miles on the "dry weather" road that crosses the middle alkali lake, a short side road to the south leads to this spring which is only about half a mile from the main road. Like many such springs the water contains easily detectable traces of radium and this spring is being exploited as a cancer sanitarium. It issues as a large steaming pool on a slight elevation above the desert which borders the alkali flat that lies between it and Cedarville. The water flows into a large tule-bordered pool and thence off into the desert. The water is very hot, but cools in the second pool where some collections were made as well as in the overflow ditch. The water is depositing small amounts of clay only. It is moderately mineralized with a specific gravity of 1.0037 and slightly alkaline (pH 8.2). No. 120b. This is really some of the overflow from the same spring which reaches the side of the main road just north of No. 120a. Here the density of the water is slightly reduced (1.0034) but the pH of 8.2 is unchanged.

No. 121. Kelly's Hot Spring, Canby, California. This is about four miles west of the town of Canby on the highway that leads to Alturas southwestward toward Redding, California, at a point 25 miles from Alturas. Here water issues at the boiling point from a large depression with considerable movement and the evolution of large bubbles of gas. The discharge, which is said to average 325 gallons a

minute is pumped in part to a swimming pool and flows in part into a meadow just below the spring. The spring does not seem to be depositing much mineral matter at present but there is much white deposit in the neighborhood, indicating that it is the remnant of a more extensive spring or group of springs previously active, and cinnabar is found in small quantities in the deposits. The overflow extends for a long distance and afforded good collecting. The water is only moderately saline (specific gravity 1.0032) with a pH of 8.4.

No. 122. Bassett Hot Spring, Bieber, California. This is about two and one-half miles northeast of Bieber which is 59 miles from Alturas on the same highway as No. 121. The water issues at the level of the surrounding ground with a flow of about 175 gallons a minute whence it is led into a large cement swimming tank. The water is moderately mineralized with a specific gravity of 1.0037 and pH of 8.4. Its composition is given as follows, in parts per million:

Sodium chloride	166.6
Calcium sulphate	66.6
Calcium acid carbonate	14.1
Sodium sulphate	488.0
Calcium carbonate	26.5
Total parts per million	761.8

The water is thus seen to be of the sulphate type, lacking in silica and magnesium.

No. 123. Big Bend Hot Springs, Henderson, California. Together with the two springs just mentioned as Nos. 121 and 122, this group issues along the course of the Pit River near the town of Henderson. Henderson may be reached from the same highway as the previous springs by going north a distance of about 18 miles on a secondary road that leaves the highway at Montgomery Creek, 40 miles northeast of Redding. The springs issue along the steep bank of the river through boulders and gravel, one well above the river and some others near its edge; one higher up supplies a bath-house (No. 123a). Our collecting was done mainly about a quarter of a mile down stream from the bath-house in the overflow from a spring which issues on the slope and flows into the river, possibly augmented by others that add to its volume, further down the slope and into the edge of the river. The specific gravity of the water varies from 1.0040 (No. 123a at bath-house) to 1.0043 (No. 123b, down stream) but the pH is 7.4 at both places.

No. 124. Mount Lassen National Park, California. This and the following thirteen locations (Nos. 124–136) are in various parts of Lassen Park and are in general characterized by their variation of hydrogen ion concentration, several showing a pH of less than 3.6 and none more than pH 7.4. No. 124 is just above the new graded road that leads from Mineral, Cal. into the park to Lake Helen, about one and one-half miles below the lake. Here the water issues in a steeply sloping meadow filled with grass and much vegetation, including many conspicuous plants of Veratrum. Through the middle of this slope there runs a streamlet of cold water, and the warm springs lie to the southern side of this with which their overflows joins. The water has a moderate specific gravity of 1.0037 and extremely low pH (3.6 or below).

No. 125. This spring lies only a few feet above the last, running off through a soft muddy gully lined with gray, clayey deposits. It is also extremely acid (pH 3.6 or less) and with a slightly higher salinity (1.0043).

No. 126. This is in the same group with the last two a few feet to the left of the others. The water has a strong odor of hydrogen sulphide and a higher pH (7.1). Its salinity is lower (1.0025).

No. 127 to 132. Bumpass Hell, Mount Lassen National Park. These are in the large depression known as Bumpass Hell which includes a great variety of steam-vents, mud-pots, boiling springs, warm springs and small seepages scattered mainly over an area of perhaps ten or fifteen acres, near the higher western portion. The activity of these springs undoubtedly varies greatly due to the supply of water from the slopes above and the quantity of melting snow present at different times. When we visited this locality previously in 1927 there was considerably more water present and the combined overflow which runs off to the south from the lower end of the basin formed a sizable warm stream of suitable size for bathing, while in 1930 with less snow on the upper slopes this stream was greatly reduced in volume. The several springs in this group are highly varied in appearance and temperature, salinity and reaction and undoubtedly also in the composition of their dissolved materials. There is much siliceous sinter about some of the hotter pools and in general the formations remind one of those in the Norris Basin in Yellowstone Park. As will be seen from the data below these springs vary considerably in salinity, but all are quite acid.

	Specific Gravity	pH
No. 127	1.0028	6.0
No. 128	1.0028	6.7
No. 129	1.0029	6.6
No. 130	1.0056	6.8
No. 132	1.0033	4.2

No. 133 to 136. Sulphur Works, Mount Lassen National Park. The formations to which this name has been given are associated with a stream that crosses the main park road at an elevation of about 6600 feet. They lie above and to the north of the road from which they are easily reached by a trail that follows the stream. There are many slopes and mounds of white and yellowish buff-colored material which has been deposited by hot springs in the past and much greenish, bluish or reddish clay of similar origin surrounds some of the springs. Nos. 133 and 134 are two pools with very acid water of pH 3.6 or less and moderate salinities of 1.0047 and 1.0043 respectively. No. 135 is a warm stream that flows over a rocky course. It contained numerous insects and tadpoles. The water is of much higher pH (7.4) and of lower salinity (1.0034). No. 136 is at the side of this same stream further down where the water is barely more acid (pH 7.3).

Nos. 137 and 138. Wilbur Hot Springs, California. These springs rise in the small canyon or valley of Sulphur Creek in Colusa County. They may be reached by road, 31 miles west of the town of Colusa, or by driving west over a very steep and winding road 21 miles from Williams which is on U. S. Highway 99. The waters from a number of springs, some of high temperature, join and form a stream that flows eastward down the valley. Our collecting (No. 137) was done at about 100 yards below the resort where the stream has a temperature of 32.8°, pH of 8.5 and very high specific gravity of 1.0217. Near the edge of the stream in a pool (No. 138) partly diluted with other, probably rain-water, the specific gravity is less, 1.0081 but the pH is the same. The water in these springs contains a large amount of sodium chloride, and gives off a very strong odor of hydrogen sulphide. It probably contains alkaline sulphides in solution as a silver coin placed in the main, most rapidly flowing spring, is completely blackened in a few seconds. It has a most unpleasant salty and sulphurous taste but is evidently quite harmless as it is drunk with impunity by the inmates of the sanitarium. There is very little mineral deposit about these springs.

No. 139. Clear Lake Park. Traveling west from Wilbur Hot Springs the road crosses the mountains after a stiff climb and again descends passing along a branch of Cache Creek at a distance of about 14 miles. This is evidently thermal water although not very warm (28.3°) with a specific gravity of 1.0053 and pH of 7.5. Some collecting was done here.

No. 140. Seigler Hot Springs, California. These springs are at a resort in Lake County, reached over a secondary road northwest from Middletown at a distance of fourteen miles. They form a group of about a dozen springs, mostly small, on the slope that borders the edge of a small creek, associated with lava rock. Our collecting was done in some pools and a sluice-way which leads the water to a bathing pool. The water is moderately saline (sp. grav. 1.0057) and nearly neutral in reaction (pH 7.3), containing much sodium and magnesium with chlorides and carbonates, but almost no sulphates.

No. 141. Calistoga, California. There are several hot springs in or near the town which lies near the head of the Napa Valley. The largest is augmented by a dug well, made into a large pleasure resort and swimming pool, and completely ruined for any biological work. Near the outskirts of the town is an intermittent spring which has been made into an artificial geyser by sinking a large iron pipe into the soil. From this the warm overflow runs along the road to form a tule-bordered stream that yielded a few specimens. The water is only slightly mineralized (sp. grav. 1.0035) with moderately alkaline reaction (pH 8.4).

No. 142. Gilroy Hot Springs, California. The springs are about twelve miles east of Gilroy over a characteristically dry and dusty secondary road which leaves the U. S. Highway 101 at Gilroy, south of San José. This place has been a resort for some sixty years, built about a moderate-sized warm spring that issues in a ravine on the slope of Coyote Creek, about 200 feet above the stream. The specific gravity of the water is 1.0049 and the pH 7.3.

No. 143. Paraiso Hot Springs, California. A number of small springs form this group which is pleasantly set near the upper end of a small valley that opens eastward into the larger Salinas Valley. It may be approached over a secondary road that leaves the U. S. Highway "101" several miles south of the town of Soledad and leads westward up the valley to the springs. The springs have been known for a long time, receiving their name from some early Catholic missionaries who selected the spot as a better place to live than the ad-

jacent lowlands. It is now a health resort and bathing place. The flow of these springs is small, but in some seepages, beneath the shadows of a group of palms that still remain as evidence of the first white inhabitants, we collected a considerable amount of material. Although said to be a cure for persons suffering from malaria, we found in these springs the only larvæ of malarial mosquitoes collected during the summer. The water has a pH of 7.4 and specific gravity of 1.0042.

No. 144. Paso Robles Mud Baths. These are on the main north and south highway "U. S. 101" about two and one-half miles north of the town of Paso Robles, California. An imposing, but deserted building and swimming pool stand as mute evidence of an attempt to popularize these mud-baths as a sanitarium. East of the building in a swamp are some warm pools and seepages with noticeable odor of hydrogen sulphide, where our collecting was done. The water has a pH of 7.4 and specific gravity of 1.0051.

No. 145. Jacumba Hot Springs. These are in the small town of Jacumba in the southeastern part of San Diego County a few miles east of the divide that separates the coastal drainage from that of the Colorado Desert and less than a mile from the Mexican boundary. Jacumba is on the transcontinental U. S. Highway "80" about 80 miles east of San Diego. The water issues in a field and along the side of a small creek, whence it is led through a ditch into a small public park where it cools considerably below the temperature of 36° noted at the source. Collecting was done both in the field and in the park. The pH of the water is 7.4, but the specific gravity varies from 1.0041 in the field to 1.0021 in the mixed flows that pass through the park.

Nos. 146 and 147. Fish Springs, California. These are on the north and south "U. S. Highway 99" close to the northwestern shore of the Salton Sea, 49 miles northwest of Brawley, Cal. One may drive to the springs over a rough road, a distance of about a mile east of the highway. The spring has been enclosed in a concrete tank which sets in a grove of small trees, surrounded by rank growth of tule and coarse grass, the tule extending over a wide area toward the shore of the Salton Sea. The temperature of the water is 30° or well below the daily summer air temperature of about 41° (106° Fahr.) which prevails at this altitude of about 200 feet below sea-level in the Imperial Valley. Nearby is another small spring (No. 147) about the same temperature and specific gravity (1.0060), but of higher pH (7.7). We visited also the "Mud Volcanoes" which lie on the edge of

the Salton Sea about 15 miles north of Brawley. These are boiling and steaming mud pots on low cones of grey clay. They were until recently below the level of the water in the sea but have now been exposed by the receding water. There is but little water and no sign of life associated with these strange formations.

Nos. 148 and 149. Democrat Springs, California. These are in the valley of the Kern River, northeast of Bakersfield, from which they may be reached by traveling about 35 miles up the river valley. There are several springs which arise near the eastern bank of the river, about 50 or 75 feet up the rather steep slope. The largest spring is used for a bath-house but the others have been only slightly disturbed. There is evidently a considerable difference in the composition of the water in the different springs as the two in which we obtained specimens differed greatly in salinity and reaction as follows: No. 148, sp. grav. 1.0017, pH 7.4; No. 149, sp. grav. 1.0047, pH 8.7.

Nos. 150–153. Mono Lake, California. This highly alkaline lake is partly fed by a number of hot or warm springs that issue at a number of places along its shore. The waters of the lake due to continual evaporation are highly concentrated showing a specific gravity of 1.0409 and an extremely high pH of more than 9.6. As can be seen from the following analysis it contains a very large amount of sodium bicarbonate and considerable borax.

Constituents in parts per million.

Potassium chloride	1,834.2
Sodium chloride	18,506.8
Sodium sulphate	9,869.0
Sodium bicarbonate	34,150.1
Magnesium bicarbonate	334.9
Calcium bicarbonate	81.0
Sodium borate	200.0
Aluminum oxide	3.0
Silica	70.0
Total solids	65,149.0

This analysis was made many years ago and probably the water is more concentrated at the present time.

In Mono Lake is Paoha Island near the western shore of which a large warm spring arises several hundred feet inland and well above the level of the lake. The overflow from this (No. 150) flows toward the lake as a small stream bordered by grass and tule. The specific

gravity of the water is 1.0045 and its pH 8.3, much lower than that of the lake. Near the eastern side of Paoha Island and reached by a trail about a mile in length which passes over a ridge of hills is another spring (No. 151). This forms a large pool about 50 feet in diameter, set in a crater like depression about 75 feet deep. This pool is said to have appeared after an explosion of gas coincident with the drilling of an oil well. It is known as Red Lake on account of the color of the water which is like that of diluted catsup. The red coloring matter is in suspension and would appear to be due to chromogenic bacteria although we were unable to more than guess at this conclusion. The only macroscopic life appears to be a slimy blue-green alga growing in quantity on submerged objects. The water is more than four times as saline as that of the lake, with a specific gravity of 1.1881 and with a pH of more than 9.6.

Along the western shore of the lake are a few warm springs that enter near the water-level. One of these (No. 153) with a specific gravity of 1.095 and pH of 9.6 yielded some specimens.

No. 154. Coso Hot Springs, California. These are near the southwest corner of Inyo County about 40 miles west of the southern part of Death Valley. They may be reached by a rather poor secondary road which extends eastward a distance of about twenty miles from the main road between Mojave and Bishop at a point about 80 miles north of the former and 100 miles south of the latter. The group includes one large spring and a number of smaller ones that cover an area of about an acre. There is a considerable amount of whitish muddy deposit, more or less covered with coarse short grasses, which borders the eastern edge of a sinter mound. In the gulch east of the springs are indications of former hot springs in the form of whitish deposits but the present activity seems to be confined to the group mentioned. The water is only slightly saline (sp. grav. 1.0036) with a pH of 7.3.

SYSTEMATIC ACCOUNT OF THE FAUNA.

The following pages contain a detailed consideration of the zoological material, mainly insects, which we collected, together with data taken from the literature relating to the fauna of thermal springs in various parts of the world, and to the relations of other animals to high temperatures. As I have cited many publications in my previous papers on this subject, only material contained in contributions since 1928 is considered, in addition to a small amount or relevant data which I had previously overlooked or failed to discuss.

PROTOZOA.

We ourselves have made no collections of Protozoa, but one paper relating to the occurrence of these animals in hot springs has recently appeared.

Ciofalo in an extensive communication to the Royal Academy of Sciences of Acireale ('27) has given an account of the fauna of a number of Sicilian hot springs. He confined his attention mainly to the Protozoa of which he lists 65 species in addition to a few mentioned only by generic names. The temperatures of these springs where his material was collected varied from below 30° to over 60° but no Protozoa were obtained in any case at temperatures of above 44°, although other springs at 46° and 50° were examined as well as some of still higher temperature. The major groups of Rhizopoda, Foraminifera, Helizoa, Mastigophora, Ciliata and Acineta are all represented and considering the completeness of Ciofalo's observations it is perfectly evident that none of these types of Protozoa are particularly resistant to high temperatures. Many of the species are apparently widespread, common forms and none, so far as indicated by Ciofalo are species restricted to thermal springs. Considering the great difficulty of making authoritative specific determinations of Protozoa from preserved specimens, the most important data in this contribution relate to the upper limits of temperature at which Protozoa were obtained.

NEMATODA.

We ourselves have made no attempt to collect nematodes in thermal waters, but since my first visit to Yellowstone Park, Hoeppli ('26) has published an account of some collections of free living nematodes made in various parts of Yellowstone Park. I have summarized his records below as they add greatly to the data that I was able previously to gather from other published sources. Most of the following species are recorded as in water of "atmospheric temperature" which probably means a summer temperature somewhere in the neighborhood of 15°–20° centigrade; some are however considerably higher.

Mononchus brachyuris Bütschli, var. *macrodenticulatus* Micoletzky. Jupiter Terrace, in water near atmospheric temperature. This is a cosmopolitan species and has been found in thermal water at Ragaz, Switzerland by Hofmanner and Menzel ('15) at a temperature of 25°.

Mononchus macrostoma Bastian. Soda Spring, at 30.5°. According to our own records Soda Spring (No. 61) is quite acid (pH 6.9) and moderately saline (sp. gr. 1.0048).

Plectus parvus Bastian. Overflow from the Castle Geyser at atmospheric temperature. Known also from soil and fresh water.

Plectus paracommunis Hoeppli. Angel Terrace at atmospheric temperature.

Trilobus gracilis Bastian, var. *allophysis* Steiner. Overflow from Castle Geyser at atmospheric temperature.

Aphelenchus parietinus Bastian. Overflow from Castle Geyser at atmospheric temperature.

Diplogaster macrura Hoeppli. Overflow from Castle Geyser at atmospheric temperature.

Macrolaimus (*Macrolaimoides*) *setosus* Hoeppli. Jupiter Terrace almost at atmospheric temperature. This group is mainly marine although a few are known to occur in brackish or fresh water and in soil.

Chromadora nana Hoeppli. Jupiter Terrace, at atmospheric temperature. A related form, *Chromadora salinarum* has been found (Linstow '01) in saline water at 32° in Europe.

Chronogaster gracilis Cobb. Overflow from mud volcano at 25°–30°.

Dorylaimus thermæ Hoeppli. In several geyser overflows in water of 38° or 40°. This would appear to be a truly thermal species, especially interesting in connection with Issel's ('06) discovery of *Dorylaimus atratus* inhabitating thermal water in Italy at 40°. This species was first discovered by Cobb, but not described by him. He reported it first from a "scum-covered, small, shallow warm spring of 53 degrees Centigrade." Cobb suspected that the nemas might be actually living in water slightly cooler, and this seems probable as Hoeppli's records are 38° in a hot pool near the Castle Geyser and 40° in a hot pool near the main road one mile from Old Faithful in the direction of the Lower Geyser Basin.

From the data so far accumulated relating to thermal nematodes, it is evident that members of this group are quite generally distributed in hot springs, and that the dearth of records is due only to a lack of interest on the part of helminthologists. No doubt some nematodes will be found to be partial to this environment, if not restricted to it.

CRUSTACEA.

Members of this group are frequently encountered in thermal waters, especially small amphipods which are often numerous in water of moderate temperature. Unfortunately I am not able to report upon the Amphipoda at present. There are also a number of

species of Ostracoda, met with less frequently, but of very great interest as certain members of this group occur in water at unusually high temperatures. An account of the distribution of the Ostracoda which we collected both in 1927 and 1930 is included in the present paper.

On one occasion a species of crayfish was taken in the stream close by the outlets of hot springs at Lava Hot Springs, Idaho, but not actually in the warm water. At this particular spot, hot water was flowing out over the surface of the stream, so that when the crayfish were removed from the bottom through the upper stratum of water they succumbed to the heat of the surface layer. Living on the bottom they are of course in cool water. They cannot therefore be included as members of the thermal fauna.

Ostracoda.

Among the collections made in 1927 were several lots of ostracod crustaceans and in 1930 a number of additional series was obtained. I have been fortunate to be able to have these identified by Mr. Charles H. Blake of the Massachusetts Institute of Technology who is particularly interested in this group. The following notes include much information kindly furnished by Mr. Blake, following the painstaking care which he gave to the two collections.

Eight species are included, and of the six which have been identified without question, all represent new species or varieties, included in five genera. This fact is rather surprising, but it must be remembered that very little collecting of these small animals has been done in the region from whence the present specimens came. From this fact it follows that it is difficult to judge whether any of the species are restricted to water of high temperature. It seems highly probable, however, that at least one form, *Potamocypris brunnea* Blake is a truly thermal species as it was taken only in water of extremely high temperature, *i. e.* at 49°–50° C., and the same is probably true of *P. varicolor* Blake collected at 44.5° and 48.3° C. Also, as is well known, at least one Algerian ostracod, *Cypris balnearia* Moniez (cited in my previous paper, 1928, p. 216) occurs only in water of high temperature. Unfortunately neither this species nor *Cypris thermalis* Costa have ever been described with sufficient accuracy to place them with certainty in any modern genus and their relationships to the species here mentioned cannot be considered at the present time.

It is of interest also, to note that in three of the species, *Chlamydo-*

theca bruesi Blake, *Potamocypris perbrunnea* Blake and *P. varicolor* Blake, both sexes are present in numbers. The species of these genera possess males only under tropical conditions, which of course are reproduced in hot springs in spite of the very cold winters which prevail over much of the area included in the present investigations.

In the short summary that follows, I have included more specific information on the occurrence of the several species.

Family Cypridæ.

Subfamily Candoninæ.

Physocypria brunnea Blake.

This was obtained at only one locality, in Hot Spring No. 91, Cleveland, Idaho in one of the pools containing water at 28.2°, specific gravity 1.0062, and pH 7.5. Most of the species of Physocypria are tropical in distribution although there are a few in the north temperate region where it is replaced by numerous species of Cadona, which is not known to extend into the tropics or southern hemisphere.

Subfamily Cyprininæ.

Cyprinotus sp. nov. ?

This species, probably undescribed, related to *C. salinus* occurring in brackish water, was obtained at two quite widely separated localities.

Number	Locality	Temperature	Specific Gravity	pH
3	Goldfield, Nevada	37.3°	1.0020	8.0
89	Indian Springs, Idaho	32.5°	1.0031	8.4

Eucypris calida Blake.

In the overflow from Hot Spring No. 150 on Paoha Island in Mono Lake, California at a temperature of 32.0° in water of specific gravity 1.0045 and pH 8.3.

Eucypris ? sp.

A species, probably of this genus was taken at three localities, all in Nevada, as follows:

Number	Locality	Temperature	Specific Gravity	pH
94	Cherry Creek, Nevada	30.4°	1.0038	8.4
97	Sunnyside, Nevada	30.8°	1.0029	9.3
101	Austin, Nevada	36.2°	1.0038	7.3

Chlamydotheca bruesi Blake.

Collections of this species were made at four localities at temperatures ranging from 31.6° to 42.0°, indicating that it is able to live at high temperatures, although quite probably not restricted to hot springs. The genus is confined to the New World and only one other species, the tropical *C. barbadensis* is known to possess males. Males of *C. bruesi* were present in the material from Battle Mt., Nevada and Cleveland, Idaho.

Number	Locality	Temperature	Specific Gravity	pH
21	Sou Hot Springs, Nevada	31.6°	1.0020	8.1
23	Battle Mt., Nevada	33.4°–42.4°	1.0008	8.0
91	Cleveland, Idaho	42.0°	1.0062	7.5
109	Gerlach, Nevada	36.6°	1.0029	8.5

Herpetocypris chevreuxi, var. **americana** Blake.

This form is a variety of an African species, which Mr. Blake informs me is so near to the typical form from Algeria that he considers it to be only a well-marked variety. We collected it in two localities as follows:

Number	Locality	Temperature	Specific Gravity	pH
97	Sunnyside, Nevada	30.8°	1.0029	9.3
120b	Cedarville, California	28.4°	1.0034	8.2

It will be noted that neither of these temperature records is very high.

Potamocypris Brady.

Potamocypris varicolor Blake.

Two lots of this species were taken at very high temperatures in northern Nevada.

Number	Locality	Temperature	Specific Gravity	pH
103	Cortez, Nevada	44.5°	1.0041	8.5
118	Denio, Nevada	48.3°	1.0030	8.4

Potamocypris perbrunnea Blake.

Number	Locality	Temperature	Specific Gravity	pH
18	Golconda, Nevada	49°–50°	1.008	8.1
20	Winnemucca, Nevada	49°–50°	1.0014	8.6

This species was taken at extremely high temperatures in these two springs which are within a short distance of one another. They were present in immense numbers in the Golconda spring and repeated observations in the shallow water near the margin of the pool showed temperatures of 49°–50°, so that there can be no mistake in the thermometer readings. This is one of the hottest locations in which we have taken living animals and the individuals were all extremely active at the time of our visit which was shortly before noon. It is evident that the preceding species is also highly adapted to heat, although the readings in the case are noticeably lower.

Family Darwinulidæ.

Darwinula Brady & Norman.

Darwinula sp.

An undetermined species of this peculiar genus was found at two localities. Aside from a few tropical species, one occurs in the north temperate zone. Our two lots were taken as indicated below.

Number	Locality	Temperature	Specific Gravity	pH
101	Austin, Nevada	36.2°	1.0038	7.3
150	Mono Lake, California	31.9°	1.0045	8.3

There are two references to Ostracoda in thermal springs that are not cited in my former papers. Issel ('06) refers to the occurrence of *Cytheridia torosa* in an Italian hot spring at a temperature of 35°–36° C., and Long early published a note on the presence of a "small bivalve testaceous animal" in a hot spring in Arkansas. The latter is undoubtedly an ostracod and the locality is quite probably the present city of Hot Springs, Ark.

Thermosbænacea.

Thermosbænidæ.

In 1924 Monod ('24) described a most remarkable abberrant Crustacean, Thermosbæna, from a hot spring (El Hamma) in north Africa near Gabes in Tunis. This form he has more recently ('27) placed in a distinct order of Malacostraca. Thermosbæna occurs in water at 45° in the pool fed by this hot spring and Monod supposes that it is a subterranean form which reaches the pool from the depths of the spring which are somewhat hotter (48°). This supposition seems rather rash since no reference is made to the animals actually emerging in the flow of subterranean water, but there seems to be no question that these crustaceans are restricted to the very warm water like Thermacarus among the mites and certain ostracod crustaceans.

Isopoda.

Aside from the few Isopoda reported in thermal springs mentioned in my former paper, there is another described in 1922 from Australia by Chilton ('22). This is a member of the family Phreatoicidæ, *Phreatoicus latipes*, discovered under peculiar circumstances in the interior desert region near Coward in central Australia. It was first found in great numbers in water from a hot water bore at a temperature not recorded, but evidently quite high as steam was rising from the surface. Later the species was found within a radius of some 30 miles in springs varying greatly in salinity and temperature from some

of which it had evidently found its way to the new source although no springs occur within several miles of the bore. The species related to this form occur in surface and underground fresh-water streams.

Acarina.

In my previous paper ('28), I have given an account of a most remarkable mite collected in several hot springs in Nevada and California during 1927. This species, *Thermacarus nevadensis* Marshall is the second species of a genus known to occur also near Lake Baikal in Siberia where it is represented by the type species, *T. thermobius* Sokolow. Thermacarus is the only known representative of the family Thermacaridæ and appears to be entirely restricted to hot springs of quite high temperature. During 1930 we secured much additional material of this species and collected also a number of other mites. Dr. Ruth Marshall has examined all of this material and has kindly identified the several forms so far as possible. Some species, represented only by immature specimens or by insufficient series are of necessity dealt with only in a preliminary way.

In addition to the species listed beyond, we encountered on several occasions extremely small, red, first stage mites swarming in dense clusters about grass stems or other small objects just above the surface of the water onto which they quickly pass when disturbed, spreading out as minute specks almost invisible to the unaided eye. I am at a loss to associate these with any of the fully developed forms that we collected. They appear to be restricted to water of rather high temperature and may perhaps represent the first stage of Thermacarus, although this is only a surmise.

Family Eylaidæ.

One Japanese species of Eylais has been described by Uchida ('27) from a hot spring in Formosa where it was collected in water at 42°. We had consequently hoped to find other representatives of this genus in North American thermal waters. We were disappointed, however, for although we obtained a species of Eylais at three widely separated localities they were nowhere in really warm water (28.2° or lower). In two places (Cleveland, Idaho; hot spring No. 91 and Gerlach, Nevada, hot spring No. 113) the water though cool showed specific gravities of 1.0062 and 1.0007, respectively giving evidence of its thermal origin.

Family Protziidæ.

Protzia sp. nov.

A species of this genus, according to Dr. Marshall undoubtedly undescribed, and probably one restricted to thermal waters was taken at a number of localities, as follows:

Number	Locality	Temperature	Specific Gravity	pH
57a	Tower Junction, Yellowstone Pk.	44.8°	1.0057	7.0
66	Firehole River, Yellowstone Pk. ..	38.4°	1.0024	8.9
67	Firehole River, Yellowstone Pk. ..	36.2°	1.0044	8.2
75	Three Sisters, Yellowstone Pk....	34.0°	1.0046	9.1
78	Biscuit Basin, Yellowstone Pk....	34°–35°	1.0040	9.6+
114	Hausen, California...............	36.2°	1.0033	7.5
150	Mono Lake, California...........	32.8°	1.0045	8.3

The field data indicate that this mite withstands rather high temperatures and so far as they extend do not suggest that it inhabits generally cool springs as the lowest temperature recorded is 32.8°. All of the springs contain a considerable amount of dissolved salts as the specific gravity ranges from 1.0033 to 1.0057. The pH covers a wide range also, from 7.0 to more than 9.6. This small genus includes a few species, several of which are represented in Europe. A species, not named, is said by Wolcott to occur in Yellowstone Park. It may be identical with the one here discussed.

Family Sperchonidæ.

Two members of this family are included in our collections. One is the well-known European *Sperchon glandulosus* Koenike which has a very wide distribution, including the United States and Canada. It appears in our collections from two hot springs as follows:

Sperchon glandulosus Koenike.

Number	Locality	Temperature	Specific Gravity	pH
75	Three Sisters, Yellowstone Pk....	34.0°	1.0046	9.1
78	Biscuit Basin, Yellowstone Pk....	34°–35°	1.0040	9.6

Both springs appear to be closely similar on the basis of specific gravity and pH.

Sperchon, or allied genus.

The other form which belongs to Sperchon or an allied genus was collected at two widely separated localities, also in water of only moderately high temperature as follows:

Number	Locality	Temperature	Specific Gravity	pH
130	Bumpass Hell, Lassen Pk.	35.6°	1.0056	6.8
150	Mono Lake, California.	32.8°	1.0045	8.3

Family Limnesiidæ.

Tyrrellia sp.

A species of Tyrrellia, probably undescribed was obtained on Paoha Island in Mono Lake, California at a temperature of 32.8°. This spring which yielded also a variety of other material has specific gravity of 1.0045 and pH of 8.3.

Family Thermacaridæ.

Thermacarus nevadensis Marshall.

During 1927 this mite was obtained at four localities and in 1930 particular care was taken to search for it as it is one of the most interesting forms that we have discovered. Eleven additional localities have now been added, greatly extending the range of the species and adding other information. The table given on the opposite page includes also the previous records secured in 1927.

The greater number of localities are in Nevada, but it also extends generally into Yellowstone Park on the north, into Idaho and northwestward to near Denio which lies on the Nevada-Oregon state line. Whether it may occur also in hot springs in Alaska is a matter of surmise, but the genus may be expected in places intermediate between the western United States and Siberia where the only other known species has been found. There seems to be no question that this mite is restricted to thermal springs as none of our temperature records are below 34° C. and the majority are much higher. Also, all specimens seen were in actively flowing springs of large size and those

Number	Locality	Temperature	Specific Gravity	pH
6	Bridgeport, California	34.0°	1.0030	7.5
7	Minden, Nevada	45.0°	1.0000	9.6
25	Deeth, Nevada	43.0°	1.0008	7.4
28	Ruby Valley, Nevada	41.8°	1.0009	9.4
68	Shoshone Basin, Yellowstone Pk.	39.2°	1.0040	9.4
77	Lower Geyser Basin, Yellowst. Pk	39.1°	1.0056	9.5
79	Sprite Pool, Yellowstone Pk.	41.0°	1.0039	8.9
87	Mountain Home, Idaho	42.6°	1.0027	9.6+
92	Cleveland, Idaho	39.1°	1.0067	8.1
100	Antelope Valley, Nevada	40.4°	1.0032	9.1
103	Cortez, Nevada	44.5°	1.0041	8.5
104	Monte Cristo, Nevada	38.3°	1.0052	8.7
108	Gerlach, Nevada	36.3°	1.0061	7.5
118	Denio, Oregon	50.8°	1.0030	8.4
123a	Henderson, California	36.8°	1.0040	7.4

giving evidence of having been present for a long time with little change, as indicated by the deposits that they had produced, present flow, etc. This is what might be expected of a small flightless purely aquatic arthropod unable to persist in water other than that of hot springs as their chances of passing from one spring to another must be very slight. The highest temperature recorded (50.8°) was in the overflow from a very large spring a few miles south of Denio, Oregon, under such circumstances that unusually accurate observations could be made. The stream formed by this spring is in places fifteen feet in width, quite deep and a large volume of water flows rapidly through it. The mites were abundant on the surface of the algæ in the water, many of them more or less inside the thick, matted, infolded masses. Under such circumstances no extensive temperature changes are possible during short periods of time and no rapid movement of the mites to cooler water along the edge of the stream is possible. This temperature therefore, represents a normal environment, where the mites were rapidly swimming or crawling about, and it represents the highest temperature record which we have been able to secure for any of the forms of animal life that we have actually collected. It is certainly well above the lethal temperature for most members of the thermal fauna.

When present, Thermacarus is usually abundant and may be seen crawling about on algæ, in the mud or frequently swimming about in the water with rather slow movements. When undisturbed, it appears to move quite decidedly faster in those springs where the water is at a higher temperature but in the absence of actual measurements no definite statement can be made.

The tolerance of this species for varying salinity and hydrogen ion concentration seems to be very great as it occurs in water of specific gravity from 1.0000 to 1.0061 and pH of from 7.4 to above 9.6. Certainly in the case of Thermacarus, temperature alone is the main factor determining its distribution, as even in winter the size of the springs in which it occurs, precludes any considerable lowering of the temperature of the medium.

INSECTS.

As before, our last series of collections contains representatives of six orders of insects. Each of these is considered in detail on the following pages.

Hemiptera.

Members of this order are not very abundant in hot springs, especially in water of rather high temperature. However, certain forms have appeared quite consistently at a series of localities. Our collections contain representatives of five families, as follows: Gerridæ, Notonectidæ, Naucoridæ, Belostomatidæ and Corixidæ.

Gerridæ.

Two species of Gerris, *G. remigis* Say and *G. gillettei* Leth. and Serv. and a single series of nymphs which cannot be determined specifically. They come from several springs (Nos. 69, 100, 123a, 131) always at very moderate temperatures, ranging as high as 34.2 in only one case. These records agree well with our previous observations and show that although purely surface species they exhibit no tendency whatever to enter the thermal environment.

Notonectidæ.

Two species of Notonectidæ obtained by us previously in hot springs were obtained again at several stations, so that we now have quite an extensive series of records.

Notonecta unifasciata Guérin (*N. indica* Linn.).

Number	Locality	Temperature	Specific Gravity	pH
3	Goldfield, Nevada	35.4°	1.0020	8.0
20	Winnemucca, Nevada	36.3°	1.0014	8.6
21	Osobb Valley, Nevada	31.6°	1.0021	8.1
23	Battle Mt., Nevada	30.0°	1.0008	8.0
28	Ruby Valley, Nevada	33.0°	1.0009	9.4
86	White Arrow Sanatarium, Nev.	30.0°	1.0040	8.6
97	Sunnyside, Nevada	30.8°	1.0029	9.3
120b	Cedarville, Cal.	28.4°	1.0034	8.2
121	Canby, Cal.	38.5°	1.0032	8.4
122	Bieber, Cal.	39.5°	1.0037	8.4

The above table which summarizes all our collections of two seasons shows quite conclusively that this Notonecta and apparently *N. kirbyi* Hungerford also, which we collected for a second time at Sunnyside, Nevada (hot spring No. 97) does not find the thermal environment very congenial. Practically all the specimens were taken in only moderately warm water, and none were seen in water at 40° or above. It is evident also, as I had surmised on the basis of our earlier observations, that Notonecta is not tolerant of a high degree of salinity since we have found it restricted approximately to the lower half of the salinity-range.

Naucoridæ.

A considerable series of specimens belonging to two species of Ambrysus were taken at several localities, serving to enlarge considerably records of the occurrence of these waterbugs in thermal springs.

Ambrysus heidemanni Montd.

Adults of *Ambrysus heidemanni* Montd. were found at three places, one of which was exactly the same station at which we first discovered it in Yellowstone Park seven years previously, indicating that it is certainly a regular inhabitant of this spring.

Number	Locality	Temperature	Specific Gravity	pH
81	Tangle Creek, Yellowstone Park	32.8°	1.0037	8.4
82	Ink Well, Yellowstone Park	30.9°	1.0038	9.6+
97	Sunnyside, Nevada	30.8°	1.0029	9.3
6	Bridgeport, Cal.	34.0°	1.0030	7.5
(1923)	Tangle Creek, Yellowstone Park	35.5°	—	—

Ambrysus pulchellus (?) Mont.

Taken at one locality, Sunnyside, Nevada in water at 33.6°, specific gravity 1.0043, pH 8.3.

Ambrysus sp.

Nymphs, most probably of *A. heidemanni* were taken in three other springs, at the following places:

Number	Locality	Temperature	Specific Gravity	pH
71	Shoshone Basin, Yellowstone Park	27.8°	1.0046	8.8
77	Lower Geyser Basin, Yel'stone Pk	38.6°	1.0056	9.5
99	Duckwater, Nev.	29.0°	1.0032	8.0
105	Pyramid Lake, Nevada	32.0°	1.0064	8.0

Arctocorixa omani Hungerford

Number	Locality	Temperature	Specific Gravity	pH
69	Shoshone Basin, Yellowstone Park	31.2°	1.0036	8.2

Trichocorixa sp.

Number	Locality	Temperature	Specific Gravity	pH
147	Fish Springs, Cal.	32.2°	1.0058	7.4

Corixid nymph

Number	Locality	Temperature	Specific Gravity	pH
150	Paoha Isl., Mono Lake...........	31.9°	1.0045	8.3

Odonata.

A very considerable number of dragon-fly and damsel-fly nymphs were obtained in 1930, representing a number of species that we had not taken previously as well as additional material of forms already contained in our 1927 series.

Nine genera and numerous species are included, but in most cases from a single or from only a few localities. A notable exception is the widespread *Mesothemis simplicicollis* now known from thermal water at ten places. None of the forms appear to be especially adapted to thermal life as the temperature records are usually rather low (rarely over 40°) and there is a wide range in the salinity of the several springs, never in excess of 1.0061 however. No nymphs were taken in any of the extremely alkaline nor except in a single instance in highly acid springs as the other pH records range from 7.4 to 9.3.

I have appended below the data upon which the foregoing remarks have been based, as well as some of the more interesting details relating to the various species.

Family Cœnagriidæ.

Argia Rambur.

There are ten series of nymphs belonging to this genus, probably representing more than one species, but I have not been able to place them with certainty as belonging to any species of which the nymphs have been described. They are included as a single group on page 232.

An unidentified species of Argia has been reported from Las Vegas, New Mexico by Needham and Cockerell ('03) in warm streams running off from the hot springs at that place, and we have one species, probably an Argia from a highly acid spring, No. 59 in Yellowstone Park (specific gravity 1.0026, pH 3.6 −).

Number	Locality	Temperature	Specific Gravity	pH
51	Mary Bay, Yellowstone Park	38.5°	1.0038	—
89	Indian Springs, Idaho	32.5°	1.0031	8.4
97	Sunnyside, Nev.	30.8°	1.0029	9.3
102	Darrough's Hot Springs, Cal.	36.5°	1.0025	9.0
103	Cortez, Nevada	40.8°	1.0041	8.5
109	Gerlach, Nevada	35.0°	1.0029	8.5
115	Surprise Valley, Nevada	33.9°	1.0027	8.3
123a	Henderson, California	37.6°	1.0040	7.4
143	Paraiso Hot Springs, California	33.4°	1.0042	7.4
149	Democrat Springs, California	31.4°	1.0047	8.7

Chromagrion conditum Hagen.

A single nymph which agrees well with Garman's description of this species ('27) was taken at hot spring No. 77 in the Lower Geyser Basin in Yellowstone Park at a temperature of 38.6°. This is a strongly alkaline spring (pH 9.5) having a specific gravity of 1.0056. The species does not appear to have been recorded from so far west hitherto.

Ischnura Charpentier.

One species of Ischnura is represented by nymphs in our collections.

Ischnura perparva ? Selys.

Nymphs which appear to belong to this widespread Western species were collected at four localities. Needham and Cockerell ('03) have reported the species as breeding in "alkali" water.

Number	Locality	Temperature	Specific Gravity	pH
—	Squaw Lake, Yellowstone Park	Cold		
104	Monte Cristo, Nevada	38.3°	1.0052	8.7
108	Gerlach, Nevada	36.3°	1.0061	7.5
109	Gerlach, Nevada	35.0°	1.0029	8.5

Family Gomphidæ.

Ophiogomphus or **Herpetogomphus**.

One large nymph belonging to one or the other of these genera was obtained at Lava Hot Springs, Idaho (hot spring No. 90) along the edge of the stream into which the springs enter, at a temperature between 33° and 40°. This is the first record known to me of any species of Gomphidæ in a hot spring.

Family Libellulidæ.

Libellula Linné.

Nymphs of Libellula were obtained at only four localities. One lot contains only a single small individual, but the others are full grown and I have been able to identify them without much question as two species. The first, taken at Cortez, Nevada in hot spring No. 103 together with nymphs of *Mesothemis simplicicollis*, is *Libellula forensis* Hagen at a temperature of 40.8°. The second, *Libellula saturata* Hagen, is more interesting as it has been previously found breeding in hot springs. I have already mentioned (Brues '24) its occurrence in Yellowstone Park on the authority of Needham ('04). The latter also records this species from White's Warm Springs, Idaho and we have now collected it in hot springs in both Nevada and California. Our data are as follows:

Number	Locality	Temperature	Specific Gravity	pH
97	Sunnyside, Nevada	30.8°	1.0029	9.3
143	Paraiso Hot Springs, Cal.	33.4°	1.0042	7.4

The temperatures are not high in any case and this species appears to be one that has extended its range into cooler regions by breeding in thermal water.

Plathemis subornata Hagen.

Nymphs which seem undoubtedly to be this species were taken at Henderson, California (hot spring No. 123a) at 37.6°, the water having a density of 1.0040 and pH of 7.4. The nymph of this species was first described as "Dythemis sp?" by Needham and Cockerell from Dimmit Lake, an alkaline pond near Roswell, New Mexico.

Orthemis ferruginea Fabr. ?

A series of nymphs from Antelope Valley, Nevada (hot spring No. 100) in water of 35.8°, specific gravity 1.0032 and pH 9.1. These agree well with Needham's description ('04), except that there is only one mental seta on each side, whereas he figures a group of four and several adjacent minute ones. My identification is therefore quite possibly incorrect.

Mesothemis simplicicollis Say.

This is the most abundant dragon-fly which we have found in the thermal springs visited. In 1927 it was obtained at three places and we are now able to add seven more localities. These are as follows:

Number	Locality	Temperature	Specific Gravity	pH
1	Hot Springs, New Mexico	39.5°	1.0039	8.1
5	Convict Lake, California	43.0°	1.0012	8.5
15	Denio, Oregon	35.2°	1.0000	8.4
44	Lewis Lake, Yellowstone Park	30.8°	1.0023	7.8
100	Antelope Valley, Nevada	35.8°	1.0032	9.1
103	Cortez, Nevada	40.8°	1.0041	8.5
104	Monte Cristo, Nevada	38.3°	1.0052	8.7
109	Gerlach, Nevada	35.0°	1.0029	8.5
114	Hausen, California	36.2°	1.0033	7.5
116	Surprise Valley, Nevada	40.2°	1.0035	7.6

Pantala flavescens Fabr.

A nymph of this species was taken at Hot Springs, New Mexico in 1927, but I failed through inadvertence to include the record in my previous account, and am now able to add another locality.

Number	Locality	Temperature	Specific Gravity	pH
1	Hot Springs, New Mexico	39.5°	1.0039	8.1
69	Shoshone Basin, Yellowstone Park	31.7°	1.0036	8.2

Plectoptera.

A comparatively small amount of material representing this order is contained in the collections obtained during 1930. It shows quite conclusively that mayflies cannot be considered as forming a part of the true thermal fauna since the temperatures recorded are consistently low, although there is a sufficient number of records for one to expect higher records if these animals actually do commonly invade water of rather high temperature.

Our collections are listed in detail below simply to demonstrate this fact. In 1927 we obtained mayfly nymphs in two springs in Nevada, also at low temperatures (31.6°–36.0°).

Callibaëtis sp.

Nymphs of a species of this genus were obtained at several localities, but always at comparatively low temperatures so that they give no indication of any tendency for these insects to adapt themselves to a really thermal environment. In addition to those listed below two collections were made in cool water, one in Squaw Lake, Yellowstone Park and in a cool pool, probably of thermal origin (sp. gr. 1.0007 and pH 8.8) near Gerlach, Nevada.

Number	Locality	Temperature	Specific Gravity	pH
97	Sunnyside, Nevada	30.8°	1.0029	9.3
123a	Henderson, California	35.0°	1.0040	7.4
140	Paraiso Hot Springs, California	33.4°	1.0042	7.4

Baëtis.

Two series of nymphs of this genus were obtained, one in cool water in Indian Pond, Yellowstone Park in water practically without salinity (sp. gr. 1.0001) and a second lot at Indian Springs, Idaho in water at 32.8°. The latter is a true thermal spring with water of a specific gravity of 1.0031 and pH of 8.4, but the temperature is by no means high.

Leptophlebia sp.

A single series of small nymphs of a species of Leptophlebia were obtained in hot spring No. 90 at Lava Hot Springs, Idaho at a tem-

perature of about 33° C. where the small springs flow directly into the creek. As there is rapid mixture of the water from the springs and that of the river the density and temperature of the spots where they were living cannot be accurately determined.

An entirely different type of mayfly nymph was taken together with the Leptophlebia mentioned above at Lava Hot Springs, Idaho (hot spring No. 90). I have been unable to identify this form, which has lateral, plate-like gills, each plate furnished below with tufts of short filamentous projections.

Trichoptera.

In spite of the general abundance of caddis worms in the several types of fresh water, few records exist of their occurrence in thermal waters. We had hoped on our last trip to secure at least a few additional records, but met with very poor success. Limnephilid larvæ were found on only three occasions, first in spring No. 47b (Indian Pond, Yellowstone Park) in water of low temperature that is practically non-saline; second in spring No. 65 (Firehole River, Yellowstone Park) in water at 32.4° and pH 8.3; third in spring No. 98 (Sunnyside, Nevada) in water of 1.0042, ρH 8.3 at 33.6°. There appear to be three species represented.

I have also a few Limnephilids of still another species given me by Mr. S. W. Denton which he collected in a hot spring west of Reno, Nevada in water of unrecorded temperature.

There can be no question that Trichoptera form a very small and unimportant part of the thermal fauna.

Although numerous Trichoptera have been collected in brackish water, with the exception of some that I have cited in my previous account, most of these occur in water of moderate salinity. Thus in his extensive lists of Finnish caddis worms from brackish water, Siltala ('06) finds many species in water with about one-half percent salt. This is approximately the salinity of many of the hot springs which we have investigated. On this basis we might expect caddis flies to be more abundant than they actually are and we must believe that temperature is the limiting factor in so greatly restricting the trichopterous fauna of thermal waters.

Diptera.

This order is abundantly represented in the thermal fauna by aquatic larvæ belonging to several families, more especially the Chironomi-

dæ, Culicidæ, Stratiomyiidæ, Tabanidæ and Ephydridæ. Of these certain chironomids and stratiomyiids frequently occur in water of especially high temperature, while certain ephydrids, as is well known, are able to develop in water of very great salinity. With the exception of a very few forms that could not be placed with any certainty, all of our collections are included in the detailed account that follows.

Chironomidæ.

A very considerable series of larvæ belonging to this family were obtained during the course of the summer, represented by nearly sixty lots. As before, we found them to be one of the very characteristic groups of the thermal fauna, represented by eight species belonging to four genera. These, together with our previous records include twelve species belonging to five genera.

They are as follows:

Tanypus monilis Linn?
Tanypus sp.
Chironomus tentans Fabr.
Chironomus sp. No. 1.
Chironomus sp. No. 2.
Chironomus sp. No. 3.
Chironomus sp. No. 4.
Orthocladius sp.
Orthocladius sp. No. 2.
Cricotopus fasciatus Panzer.
Cricotopus sp.
Tanytarsus exiguus Johannsen.

Fully one-third of the springs where we were able to make collections yielded specimens, usually in considerable abundance, although since most of the forms live in mud they are to be found frequently only on rather close examination. As will be seen from the data on the following pages, several species, notably *Chironomus tentans*, *Chironomus* sp. No. 2 and *Chironomus* sp. No. 4 occur commonly at temperatures of 40° or above, although so far as can be stated at present none appear to be restricted to thermal waters.

Of two of these forms, *Chironomus tentans* and *Chironomus* sp. No. 4 we were fortunate to secure a long series of records and these show clearly that in the case of these species at least, the hydrogen ion concentration of the water seems to play an important rôle in de-

termining their occurrence in hot springs. Thus the first is typically an inhabitant of acid waters and the second of alkaline ones. None of the records include any springs of very high salinity, *i. e.* above 1.0062, in spite of the fact that some other members of this family occur in strongly brackish water or in the sea.

One striking feature of the present list is the recurrence of species which we took previously at other localities, a fact which indicates a greatly limited thermal fauna, notwithstanding the large extent of the family Chironomidæ.

Chironomus tentans Fabr.

This species which has been provisionally identified and referred to in my two previous publications ('24; '28) was taken again at eleven localities, all of them in Yellowstone Park. In each case the larvæ were taken in acid water (pH 3.6 — to 7.9) and we have a previous record of pH 8.8. Thus, although there is considerable range, it is very clear that the species occurs generally in acid waters, whereas a species such as *Chironomus* sp. No. 4 prefers alkaline water ranging from pH 7.1 to 9.6. These two species show without question that the reaction of the water is an important factor in determining their distribution.

Number	Locality	Temperature	Specific Gravity	pH
38	West Thumb, Yellowstone Park ..	34.2°	1.0025	6.8
39	West Thumb, Yellowstone Park ..	36.8°	1.0039	6.3
40	West Thumb, Yellowstone Park ..	37.0°	1.0058	7.3
45	Norris Geyser Basin, Yell. Pk....	44.8°	1.0040	7.9
49	Beach Springs, Yellowstone Park .	39.5°	1.0051	7.2
58	Whirligig Geyser, Yellowstone Pk.	38.2°	1.0051	3.6—
59	Near Minute Man, Yell. Pk......	25.4°	1.0026	3.6
63	Amphitheatre Springs, Yell. Pk. ..	30.6°	1.0043	3.6—
72	Shoshone Geyser Basin, Yell. Pk..	35.8°	1.0062	7.7
73	Shoshone Geyser Basin, Yell. Pk..	40.1°	1.0058	3.6
74	Shoshone Geyser Basin, Yell. Pk..	35.3°	1.0047	6.4

Chironomus sp. No. 2.

This species which we took previously ('28) in Lassen National Park in hot spring No. 12 reappeared in our last series of collections from five localities in Yellowstone Park and one in Mt. Lassen Park.

Most of the larvæ were living in water of slightly or highly alkaline reaction, as can be seen from the following list of stations.

Number	Locality	Temperature	Specific Gravity	pH
38	West Thumb, Yellowstone Park ..	34.2°	1.0025	6.8
81	Tangle Creek, Yellowstone Park..	30.0°	1.0037	8.4
82	Ink Well, Yellowstone Park......	30.0°	1.0038	9.6+
83	Ink Well, Yellowstone Park......	36.6°	1.0039	9.1
84	Near Spasmodic Geyser, Yell. Pk.	41.0°	1.0032	9.3
126	Mount Lassen Park.............	22.2°	1.0025	7.1

Chironomus sp. No. 4.

This species which we took at a series of localities in 1927 was again well represented in our collections made in 1930. The very characteristic shape and dentition of the labium make it easily recognizable and there can be no doubt that all the larvæ belong to a single species, although there is some slight variation in the form of the pale colored median teeth; these are sometimes less acute than in the specimen figured (Brues '28; fig. 4, no. 12).

The following list includes twelve additional records for this species:

Number	Locality	Temperature	Specific Gravity	pH
77	Lower Geyser Basin, Yell. Park...	38.6°	1.0056	9.5
78	Biscuit Basin, Yellowstone Park..	35.6°	1.0040	9.6+
95	Cherry Creek, Nevada...........	30.4°	1.0043	8.4
100	Antelope Valley, Nevada.........	40.4°	1.0032	9.1
102	Darroughs Hot Springs, Nevada..	40.8°	1.0025	9.0
103	Cortez, Nevada.................	40.8°	1.0041	8.5
104	Monte Cristo, Nevada...........	38.3°	1.0052	8.7
114	Hausen, California..............	36.2°	1.0033	7.5
116	Surprise Valley, Nevada.........	40.2°	1.0035	7.6
123a	Henderson, California............	35.0°	1.0040	7.4
147	Fish Springs, California..........	32.2°	1.0060	7.7
150	Paoha Island, Mono Lake, Cal....	38.3°	1.0045	8.3

Together with eight localities listed in my previous paper it is clear that the larvæ of this form occur very generally in water of high

temperature as there are eight records from water above 40°, ranging as high as 43.0°. The range with reference to hydrogen ion concentration is mainly in the alkaline side, from 7.1 to 9.6, but only two records are below 7.5.

Two lots of larvæ from hot spring No. 87 at Mountain Home, Idaho (pH 9.6 +; sp. gr. 1.0027) and No. 114 at Hausen, California (pH 7.5; sp. gr. 1.0033) are similar to the above species, but differ in the form of the labium which has the teeth more widely spaced in the central group of four and the small lateral tooth more clearly separated. They may represent another species.

Tanytarsus exiguus Johannsen.

One series of larvæ seem to belong to this species which is already known from the eastern United States and from Idaho. They were collected in hot spring No. 97 at Sunnyside, Nevada, in water of 1.0029, pH 9.3 at a temperature of 30.8°.

Cricotopus trifasciatus Panzer.

Numerous larvæ which agree with the description and figure of this species were taken in hot spring No. 66 near the bank of the Firehole River in Yellowstone Park. This is a widespread holarctic form whose larva has been described by Malloch ('15). The labium has a rounded median tooth, a bifid lateral tooth and a gradually decreasing series beyond. The specimens were in water at 38.4°, pH 8.9; specific gravity 1.0023.

Cricotopus sp.

This is the same species that we collected in 1927 at Beowawe, Nevada in highly alkaline water having a pH of 9.6 or over. It appeared at four other localities in Yellowstone Park in water of moderately or strongly alkaline reaction, but always at low or moderately low temperatures.

Number	Locality	Temperature	Specific Gravity	pH
43	West Thumb, Yellowstone Park ..	23.2°	1.0023	9.0
72	Shoshone Geyser Basin, Yell. Pk..	35.4°	1.0062	7.7
75	Three Sisters, Yellowstone Park . .	37.2°	1.0046	9.1
83	Ink Well, Yellowstone Park......	36.6°	1.0039	9.1

Orthocladius sp.

This form was found in one of our previous collections from Steamboat Springs, Nevada (hot spring No. 8) and we collected it again in 1930 at two localities as follows:

Number	Locality	Temperature	Specific Gravity	pH
89	Indian Springs, Idaho............	32.5°	1.0031	8.4
121	Kelly Hot Springs, Canby, Calif..	38.5°	1.0032	8.4

Orthocladius sp. No. 2.

A series of larvæ taken in hot spring No. 80, Firehole Pool, Yellowstone Park represent a species quite similar to one figured by Malloch ('15, plate 29, fig. 17) as Orthocladius, sp. E. The labium is more pointed medially so that the minute lateral teeth set further back on the sides and it may represent another species; it is quite clearly different from the Orthocladius recorded above and in my previous paper ('28, p. 189). The larvæ were at a temperature of 34°, sp. gr. 1.0046, pH 8.2.

Dixidæ.

The larva of a species of Dixa was obtained in Indian Pond, Yellowstone Park in cool water. However, this is not truly thermal water as the specific gravity is very low, only 1.0001 in spite of numerous small thermal springs that surround its shores. We found it in none of the truly thermal, warm, saline waters and may probably regard the group as not adapted to such an environment.

Culicidæ.

In the present collections four species are represented by fifteen lots of specimens collected in twelve different springs. None of these were found at very high temperatures, and with the data that we have secured in previous years in this region, the statement may be made that mosquitoes do not readily adapt themselves to life in hot springs.

Culex tarsalis Coquillett.

This widespread species seems to be the commonest mosquito found breeding in thermal waters in the region investigated, as we obtained larvæ on nine occasions. Seven other records are contained

in my previous paper ('28) so that we now have a fairly accurate notion concerning the requirements of this species. As the series is so complete, I have combined the present data with those relating to the other springs in the same region.

Number	Locality	Temperature	Specific Gravity	pH
1	Hot Springs, New Mexico	39.0°	1.0039	8.1
5	Convict Lake, Calif.	35.2°	1.0012	8.8
7	Minden, Nevada	30.0°	1.0000	8.8
23	Battle Mountain, Nevada	36.0°	1.0008	8.0
23a	Battle Mountain, Nevada	36.0°	1.0021	8.5
26	Wells, Nevada	35.2°	1.0018	7.9
28	Ruby Valley, Nevada	35.6°	1.0009	9.4
37	West Thumb, Yellowstone Park	Cool	1.0056	8.9
38	West Thumb, Yellowstone Park	34.2°	1.0025	6.8
61	Soda Spring, Yellowstone Park	29.0°	1.0048	6.9
72	Shoshone Basin, Yellowstone Park	35.4°	1.0062	7.7
113	Soldier Meadow, Nevada	Cold	1.0007	8.8
121	Canby, California	38.5°	1.0032	8.4
138	Wilbur Hot Springs, California	28.0°	1.0081	8.5
143	Paraiso Hot Springs, California	33.4°	1.0042	7.4
145	Jacumba Hot Springs, California	36.0°	1.0041	7.4

Although usually in quite alkaline water, the larvæ occur at a lower pH than my previous records showed as one pool at West Thumb in Yellowstone Park contained larvæ thriving at pH 6.8. They show also great tolerance with respect to dissolved salts as the specific gravity of the water in the several springs ranges from 1.0000 to 1.0081 as determined in the field.

Aëdes pullatus Coq.

Larvæ of this species were collected in highly acid water with a pH of 3.6 or less near the eastern shore of Turbid Lake in Yellowstone Park, in company with larvæ of Ephydra. This is ordinarily a snow-water form, but in the present instance although the water was cold at the place the larvæ were taken its specific gravity was 1.0025.

Culicella inornata Williston.

The stout-bodied larvæ of this species were encountered at three stations, all in California.

Number	Locality	Temperature	Specific Gravity	pH
129	Bumpass Hell, Lassen, N. P.	27.6°	1.0029	6.6
138	Wilbur Hot Springs, California	28.4°	1.0081	8.5
143	Paraiso Hot Springs, Cal.	33.4°	1.0042	7.4

As there seems to be some variation in the insertion of the tufts of the anal brush there may be a possible error in the determination of this species, since some of the specimens in two of the lots will run to *C. maccrackenæ* in Dyar's table on the basis of this character. I am reasonably certain, however, that the larvæ are all *C. inornata*. The occurrence of this species in the overflow from the Wilbur Hot Springs shows that it will endure a considerable concentration of salts, which agrees well with the data cited in my previous paper ('28, p. 185) concerning the related *C. incidens* Thomson.

Anopheles pseudopunctipennis Theobald.

This malarial mosquito was collected at two places:

Number	Locality	Temperature	Specific Gravity	pH
143	Paraiso Hot Springs, Cal.	33.4°	1.0041	7.4
147	Fish Springs, Cal.	33.2°	1.0060	7.7

These records are of considerable interest as this species of Anopheles seems to be the only one that has been found in thermal waters. As cited in my earlier paper ('24, p. 394) it has been twice taken in truly thermal water, once in Peru and again in the Las Vegas hot springs in New Mexico. As this species is a common carrier of malaria its presence in the Paraiso Hot Springs might easily interfere with the advertised efficacy of the water as a cure for malaria.

Simuliidæ.

We have collected only a single lot of larvæ belonging to this family during the course of our work and I have found no published records of them from hot springs. However, since my previous paper was published, my friend Mr. S. W. Denton visited a number of

hot springs in the west and brought back some insects. Among these is a single larva of Simulium from Lawton hot spring, near Ashland, Oregon.

We found larvæ of a species *Simulium* in very large numbers attached to stones in the overflow from hot spring No. 135 near the "Sulphur Works" in Lassen National Park at a temperature of 30.6° C. This water has a specific gravity of 1.0034 and pH of 7.4. The larva collected by Mr. Denton belongs to the same species as nearly as I can tell, but I have been unable to identify them. The larvæ agree well with Malloch's description (Malloch '14) of *S. vittatum* Zett. and I had provisionally regarded them as this species, but the discovery of a single pupa in the lot makes this determination doubtful unless the pupa belongs to a different species, which does not seem probable. The pupa has only 10 branches to the respiratory filaments, whereas *vittatum* has sixteen. *S. jenningsi* Malloch has ten, but my larvæ do not agree with this species. It seems probable therefore that they belong to some species of which the preparatory stages have not yet been described.

Stratiomyiidæ.

Forty-three lots of larvæ of Stratiomyiidæ are contained in the present collections, mainly species of Stratiomyia and Odontomyia. Members of this family develop under the most diverse situations almost always in rather acid waters of pH 8.5 or below, although the range for the individual species is usually rather wide. In one very striking case however, larvæ of a peculiar species of Stratiomyia with unusually long anal segments were taken only in extremely acid springs. This species (*Stratiomyia* No. 6) was collected in four springs, all having a pH of less than 3.6.

Without question the preference for generally acid springs is related to the need for calcium carbonate which is regularly deposited in the integument of the larvæ. Johannsen has pointed out that these larvæ always bear considerable amounts of this substance in the integument regardless of whence they may have come, and notes that it may be removed by immersing the larvæ in dilute hydrochloric acid for a few moments. Following this procedure in the preparation of specimens for study, I have noted no cases among the hot springs material in which the effervescence failed to occur.

Much of the present material represents species found in our collections of previous years, but there are several additional species

and a much greater series of some of the forms, as will be evident from the following more detailed statement.

Stratiomyia sp. No. 1.

This seems to be the most abundant species in the hot springs we have examined as there are eight localities represented in the 1930 collections. These together with three previous records show the following distribution.

Number	Locality	Temperature	Specific Gravity	pH
5	Convict Lake, California	35°	1.0012	8.5
11	Bumpass Hell, Lassen	30°–40°	1.0016	5.7–6.5
13	Drakesbad, Lassen	28°	1.0021	6.7
46b	Bijah Spring, Yellowstone Park	34.3°	1.0036	6.5
57a	Tower Junction, Yellowstone Pa k	36.5°	1.0057	7.0
91	Cleveland, Idaho	39.1°	1.0062	7.5
103	Cortez, Nevada	40.8°	1.0041	8.5
—	Cortez, Nevada	Cold	—	—
113	Gerlach, Nevada	Cold	1.0007	8.8
116	Surprise Valley, Nevada	40.2°	1.0035	7.6
123a	Henderson, California	36.0°	1.0040	7.4
135	Sulphur Works, Lassen	32.6°	1.0034	7.4

There is some variation in these larvæ, but I cannot separate them into groups and think all must represent one species. It will be noted that there is a well-marked tendency for this form to occur in more acid springs than most other Stratiomyiidæ. Also it was not taken at very high temperatures and was found in two cold springs as well.

Stratiomyia sp. No. 3. (Fig. 2, A).

A rather large, heavy-bodied larva with the body segments very strongly constricted off from one another, especially on the posterior half of the body. Body above not strongly pigmented, except the puparia, which are almost black. All except the first and last body segments with five narrow longitudinal dorsal blackish stripes. These are most conspicuous on the anterior part of the first three segments and on the posterior part of the last three (exclusive of terminal segments) segments since at these places the space between the stripes

is strongly decolored. Body hairs weak and pale-colored. Sides of body segments strongly bulging between the sutures which thus appear to be much more constricted than usual even in small specimens. Terminal segment (Fig. A) twice as long as wide at base, the anal slit placed near the base; ventral surface with a curved row of small setæ near base and four arranged in a quadrilateral beyond the middle.

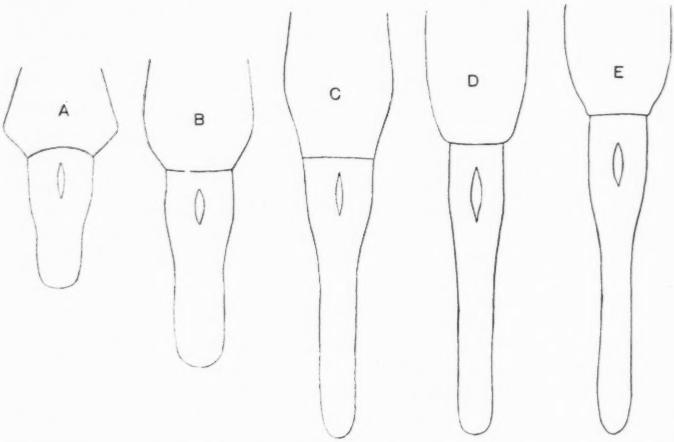

FIGURE 2. Outlines of apices of abdomen in ventral view of larvæ of several species of Stratiomyia. A, Stratiomyia, sp. No. 3; B, Stratiomyia sp. no. 4; C, Stratiomyia, sp. No. 5; D and E, Stratiomyia sp. No. 6.

This species was not obtained in 1927, but appears in the material from four widely separated localities in the later collections. These are as follows.

Number	Locality	Temperature	Specific Gravity	pH
91	Cleveland, Idaho	38.0°	1.0062	7.5
128	Bumpass Hell, Lassen	34.2°	1.0028	6.7
140	Siegler Hot Spring, Calif.	42.8°	1.0057	7.3
143	Paraiso Hot Spring, Calif.	33.4°	1.0042	7.4

The specimens vary considerably in size, the puparia measuring from 25–30 mm. in length.

Stratiomyia sp. No. 4. (Fig. 2, B).

A rather long slender species with elongate terminal segment. Body segments separated by moderately deep constrictions that are more conspicuous in fully matured specimens, especially behind. Body very dark above, the five dorsal longitudinal dark bands practically continuous along the entire length of the body. Surface quite strongly pale hairy, each segment at the lateral edge bearing two stouter setæ. Terminal segment (Fig. 2, B) slightly less than three times as long as wide at base; with a curved row of four setæ near base, one at each side of the slit near middle, one at middle of lateral margin, four minute ones in a quadrilateral just behind the middle. Mature length about 25–30 mm.

This species is similar to the one designated as No. 2 and may be the same, but the body is very conspicuously striped in all of five specimens. They come from hot spring No. 128 in Bumpass Hell, Mt. Lassen National Park in water of a density of 1.0028 and pH of 6.7, at a temperature of 34.2°.

Stratiomyia sp. No. 5. (Fig. 2, C).

A large, pale species with long, tapering terminal segment. Entire length 35 mm.; terminal segment 6 mm. Constrictions between body segments weak anteriorly; more noticeable, but not deep behind. Pigmentation weak, the dorsal longitudinal bands more conspicuous on the segments behind where the body color between them is almost white; almost obliterated on the anterior part of the segments where the body color is darker, the median band, however, practically continuous. Body above rather sparsely hairy, the hairs on the lateral margin unusually dense; no larger setæ present however on the lateral margins. Terminal segment (Fig. C) long and slender, slightly more than four times as long as wide at base, its bristles very weak.

Two specimens from hot spring No. 128 in Bumpass Hell, Mt. Lassen National Park, California taken in company with the previous species in water of a density of 1.0028, pH 6.7 and temperature of 34.2°. It is at once distinguished from all the larvæ of Stratiomyia we have collected, except the one following (No. 6) by its very long terminal segment.

Stratiomyia sp. No. 6. (Fig. 2, D, E).

A large species, the mature larvæ from 32–40 mm. in length with extremely long slender terminal segment. Color usually very dark above, the median dorsal stripe quite distinct, but the lateral ones clearly indicated only near the sutures by paler spots which lie between the stripes. In specimens that appear to be entirely mature they have the color more uniform with the stripes practically absent. Dorsal surface more or less white pilose, the lateral margins without any conspicuous enlarged setæ. Terminal segment extremely long, measuring from 10 to 12 mm. in length and about 5 or 6 times as long as wide (Fig. D, E).

This species was obtained only in Yellowstone Park, in four extremely acid hot springs where the pH is below 3.6, the lower limit at which we could make colorimetric determinations. It is no doubt restricted to such highly acid water. I have also several larvæ which seem to be the same, taken in a hot spring at Banff, Canada by Mr. D. J. Zinn.

The localities are as follows:

Number	Locality	Temperature	Specific Gravity	pH
53	Turbid Lake, Yellowstone Park ..	37.8°	1.0034	3.6–
58	Whirligig Geyser, Yellowstone....	38.2°	1.0051	3.6–
59	Near Minute Man, Yellowstone ..	25.4°	1.0026	3.6–
63	Amphitheatre Springs, Yellowstone	39.4°	1.0043	3.6

Odontomyia sp. No. 1.

This species was originally taken by us at Hot Springs, New Mexico, but there is in the present collection another specimen apparently the same from Soda Spring (hot spring No. 61) in Yellowstone Park. Considering the wide difference in location however, I hesitate to consider them as identical. A third locality is also listed below.

Number	Locality	Temperature	Specific Gravity	pH
1	Hot Spring, New Mexico.........	38.7°	1.0039	8.1
61	Soda Spring, Yellowstone........	29.0°	1.0048	6.9
101	Austin, Nevada.................	36.2°	1.0038	7.3

Odontomyia sp. No. 2.

Larvæ of this undetermined species were taken at three localities during 1927 and five additional lots were secured in 1930. The species is not at all restricted in occurrences either in regard to temperature or specific gravity.

Number	Locality	Temperature	Specific Gravity	pH
4	Silver Peak, Nevada	39.6°–46.7°	1.0212	8.3
10	Brokeoff, Mt. Lassen	43°–47°	1.0014	7.3
22	Battle Mt., Nevada	38°	1.0014	7.8
101	Austin, Nevada	36.2°	1.0038	7.3
103	Cortez, Nevada	44.5°	1.0041	8.5
113	Gerlach, Nevada	Cold	1.0007	8.8
123a	Henderson, California	37.6°	1.0043	7.4
135	Sulphur Works, Lassen	32.6°	1.0034	7.4

All the records are from springs with moderately high hydrogen ion concentration.

Odontomyia sp. No. 3.

We encountered this species only once, and then not alive in a hot spring near Golconda, Nevada in 1927, but last year it appeared in our collection from three other localities.

Number	Locality	Temperature	Specific Gravity	pH
18	Golconda, Nevada	Dead specimens	1.0008	8.1
57a	Tower Junction, Yellowstone	36.5°	1.0057	7.0
91	Cleveland, Idaho	39.1°	1.0062	7.5
94	Cherry Creek, Nevada	30.4°	1.0038	8.4
103	Darrough's Hot Spring, Nevada	36.5°	1.0025	9.0

Odontomyia sp. No. 4.

This form we took previously only twice in our 1927 collections.

Number	Locality	Temperature	Specific Gravity	pH
57a	Tower Junction, Yellowstone	36.5°	1.0057	7.0
61	Soda Spring, Yellowstone	39.2°	1.0048	6.9
103	Cortez, Nevada	44.5°	1.0041	8.5
123a	Henderson, California	37.6°	1.0043	7.4
147	Fish Springs, California	32.2°	1.0058	7.7
	Unrecorded locality	40.8°	—	—

The three records of unusually high temperatures indicate a great tolerance to heat.

Odontomyia sp. No. 5.

Two lots of larvæ are apparently this species, although most of the specimens are considerably larger than the original ones from Mount Lassen Park. All are from water of quite or very high temperature.

Number	Locality	Temperature	Specific Gravity	pH
10	Brokeoff Mountain, Mt. Lassen	47°	1.0014	7.3
61	Soda Spring, Yellowstone	29.0°	1.0048	6.9
91	Cleveland, Idaho	39.1°	1.0062	7.5
101	Austin, Nevada	36.2°	1.0038	7.3
109	Gerlach, Nevada	36.6°	1.0029	8.5

Oxycera (?) sp.

The same species which I referred to this genus with some doubt, in 1928 (p. 197) was taken again at several widely separated localities in Yellowstone Park, Idaho and California in water of rather uniformly high temperature. As indicated by the data given below there is a rather wide variation in the specific gravity of the water in the

several springs (1.0014 to 1.0067) but the hydrogen ion concentration ranges only from 7.0 to 8.3. I have also a larva collected in a hot spring at Banff, Canada by Mr. D. J. Zinn. It is quite evident that this species occurs very generally in thermal springs.

Number	Locality	Temperature	Specific Gravity	pH
10	Brokeoff, Mt. Lassen	43°–47°	1.0014	7.3
57	Tower Junction, Yellowstone	36.5°	1.0057	7.0
60a	Angel Terrace, Yellowstone	38.0°	1.0040	8.3
91	Cleveland, Idaho	39.1°	1.0062	7.5
92	Cleveland, Idaho	36.7°	1.0067	8.1
101	Austin, Nevada	36.2°	1.0038	7.3
135	Sulphur Works, Lassen	32.6°	1.0034	7.4
140	Siegler Hot Spring, California	42.8°	1.0057	7.3

In addition to the material listed above, there is a single peculiar larva of small size (about 5 mm. in length) from hot spring No. 57, at Tower Junction in Yellowstone Park. This bears a transverse series of large, spatulate, fimbriately margined bristles on the body segments. Each series includes four dorsal bristles and a marginal one at each side. It may possibly belong to Nemotelus or some related genus.

Tabanidæ.

Fifteen lots of larvæ of this family were obtained in 1930, all similar and in all probability referable to *Tabanus punctifer* O. S. Previously we obtained larvæ of this species at several localities and adults are commonly seen in the neighborhood of hot and alkaline bodies of water. There is a great difference in the size of the individual larvæ, some being quite small and others evidently nearly mature. The species always develops in alkaline water; our records indicate a pH of 7.4 to 9.6, and it is peculiarly tolerant of highly saline water as we have found it in water ranging as high as 1.0146 at Hot Springs, Utah and 1.0217 at Wilbur Hot Springs, California, the latter water being the vilest we have ever attempted to taste. On six occasions the larvæ were at a temperature of over 40°, showing also a high tolerance for heat.

Below are the combined records of our two years' collections:

Number	Locality	Temperature	Specific Gravity	pH
5	Convict Lake, California	43.0°	1.0012	8.5
6	Bridgeport, California	38.5°	1.0030	7.5
20	Winnemucca, Nevada	38.0°	1.0014	8.6
24	Beowawe, Nevada	39.6°	1.0020	9.6
31	Hot Springs, Utah	35.3°	1.0146	8.2
32	Ogden Canyon, Utah	—	1.0063	8.3
51	Mary Bay, Yellowstone Park	38.5°	1.0038	—
71	Shoshone Basin, Yellowstone Park	40.8°	1.0046	8.8
77	Lower Geyser Basin, Yell. Park	38.6°	1.0056	9.5
94	Cherry Creek, Nevada	36.3°	1.0038	8.4
95	Cherry Creek, Nevada	36.3°	1.0043	8.4
100	Antelope Valley, Nevada	40.4°	1.0032	9.1
102	Darrough's Hot Springs, Nevada	38.2°	1.0025	9.0
103	Cortez, Nevada	40.8°	1.0041	8.5
104	Monte Cristo, Nevada	38.3°	1.0052	8.7
106b	Pinnacles, Pyramid Lake, Cal.	33.6°	—	8.4
116	Surprise Valley, Nevada	40.2°	1.0035	7.6
118	Denio, Oregon	42.2°	1.0030	8.4
123a	Big Bend Hot Spring, Cal.	37.6°	1.0040	7.4
137	Wilbur Hot Springs, Cal	32.8°	1.0217	8.5
143	Paraiso Hot Spring, Cal	33.4°	1.0042	7.4

Ephydridæ.

Our previous collections made in 1927 contained five series of larvæ belonging to the genus Ephydra and in 1930 we were able to add 24 additional records. More than one species may be present, but I have been unable to distinguish them satisfactorily. Only two lots come from highly saline water, one from Wilbur Hot Springs (No. 137) and one from warm seepage along the shore of Mono Lake. The latter are probably *Ephydra hians* Say which occurs abundantly in the still more highly saline waters of the lake itself as well as in various other saline and alkaline bodies of water in the Western United States. Possibly the others are also the same species as I cannot distinguish them after a rather careful examination and they agree with the description given by Aldrich ('12) of *E. hians* which he obtained in several widely separated localities. Unfortunately there is much yet to be learned concerning the actual distribution of the

several species of Ephydra that occur in the far western states and I have already recorded the occurrence of *E. pectinulata* Cresson in a spring in the Norris Geyser Basin in Yellowstone Park ('24). These larvæ are also indistinguishable so far as I can see from those in my present collections, so that these may represent this species, at least in part, especially since most of the series are from locations in Yellowstone Park.

By comparison with the series of determinations which we made of the hydrogen ion concentration of the water at each location, the collections of Ephydra larvæ at once group themselves into two series. One contains 18 lots taken in springs of fairly or very high pH, ranging from 6.5 to 9.6 + and the other includes six lots all from very strongly acid water of pH 3.6 or less. This may not be important since there were very few springs in which the water did not fall into one or the other of these groups. However, I have listed the two series separately below.

Ephydra sp. probably[1] *E. pectinulata* Cress.

Number	Locality	Temperature	Specific Gravity	pH
43	West Thumb, Yellowstone Park ..	23.2°	1.0023	9.0
48	Indian Pond, Yellowstone Park ...	28.4°	1.0028	6.5
49	Beach Springs..................	35.0°	1.0051	7.2
56	Turbid Lake, Yellowstone Park...	40.6°	1.0040	7.2
57b	Tower Junction, Yellowstone Park	40.2°	1.0057	7.0
66	Firehole River, Yellowstone Park.	38.4°	1.0024	8.9
68	Shoshone Basin, Yellowstone Park	39.2°	1.0040	9.4
71	Shoshone Basin, Yellowstone Park	40.8°	1.0046	8.8
75	Three Sisters, Yellowstone Park ..	36.0°	1.0046	9.1
76	Sunset Lake, Yellowstone Park...	32.2°	1.0043	9.0
77	Lower Geyser Basin, Yell. Park ..	33.9°	1.0056	9.5
79	Sprite Pool, Yellowstone Park....	36.3°	1.0039	8.9
80	Firehole Pool, Yellowstone Park..	36.0°	1.0046	8.2
83	Near Ink Well, Yellowstone Park.	39.3°	1.0038	9.1
84	Near Spasmodic Geyser, Yell. Pk.	32.3°	1.0032	9.3
93	Preston, Idaho..................	36.0°	1.0150	8.0
137	Wilbur Hot Springs, Calif........	32.8°	1.0217	8.5
149	Democrat Springs, Calif.	24.8°	1.0047	8.7
153	Shore of Mono Lake, Calif........	18.8°	1.0195	9.6+

[1] Except Numbers 137 and 153.

Ephydra sp., perhaps *E. pectinulata* Cress.

Number	Locality	Temperature	Specific Gravity	pH
52	Turbid Lake, Yellowstone Park . .	19.3°	1.0025	3.6
53	Turbid Lake, Yellowstone Park . .	37.8°	1.0034	3.6
58	Whirligig Geyser, Yellowstone Pk.	38.2°	1.0051	3.6 –
59	Near Minute Man, Yell. Park	24.6°	1.0026	3.6 –
63	Amphitheatre Springs, Yell. Pk. . .	27.4°	1.0043	3.6
73	Shoshone Basin, Yellowstone Park	40.1°	1.0058	3.6

In addition to the above, there are three lots of larvæ which seem referable to this family. They are small (8–10 mm. in length) with cylindrical body beset with minute black bristly hairs arranged much as in Ephydra, but without the stout segmentally disposed rows of hooks characteristic of that genus. The respiratory apparatus is a forked tube, each branch of which is tipped with a heavily chitinized dark brown cylinder as in Ephydra.

The localities are as follows:

Number	Locality	Temperature	Specific Gravity	pH
57a	Tower Junction, Yellowstone Park	39.2°	1.0057	7.0
61	Soda Spring, Yellowstone Park . . .	29.0°	1.0048	6.9
95	Cherry Creek, Nevada	30.4°	1.0057	8.4

Coleoptera.

The beetle fauna of thermal springs is very abundant and varied, including members of most of the purely aquatic families. The present collections contain representatives of Haliplidæ, Dytiscidæ, Hydrophilidæ, Helmidæ and Heteroceridæ, but no Gyrinidæ, although a Gyrinus was taken by us in 1927, and if notice had been taken of riparian, mud-inhabiting forms several other groups would have been added.

Altogether many hundreds of specimens were taken and had it not been for the kind interest of Mr. C. A. Frost, who has undertaken to identify the material I should have been unable to give any account of them. Mr. H. C. Fall has also examined some of the material

which was sent to him by Mr. Frost and the series of Laccobius and Helophorus have been in the hands of Mr. F. E. Winters. To these gentlemen I am also greatly indebted.

The following detailed account includes all of the species collected, with the exception of the Helmidæ and a very few others that could not be definitely determined.

HALIPLIDÆ.

Peltodytes callosus Lec.

This species was taken at two places in California in addition to a spring in Mt. Lassen Park listed in my previous paper ('28).

Number	Locality	Temperature	Specific Gravity	pH
120b	Cedarville, California.	36.2°	1.0037	8.2
122	Henderson, California.	39.5°	1.0040	7.4

DYTISCIDÆ.

Deronectes (*Hydroporus*) **griseostriatus** Deg.

Number	Locality	Temperature	Specific Gravity	pH
96	Monte Neva, Nevada.	36.3°	1.0038	8.4
119	Fish Springs, Nevada.	Cold	1.0002	—

Deronectes striatellus Lec.

This species was taken in six hot springs of very different character over a wide geographical range, but not at very high temperatures.

Number	Locality	Temperature	Specific Gravity	pH
64	Amphitheatre Springs, Yell. Pk. . .	34.2°	1.0043	3.6−
75	Three Sisters, Yellowstone Park. .	37.2°	1.0046	9.1
78	Biscuit Basin, Yellowstone Park. .	35.0°	1.0040	9.6+
119	Fish Springs, Nevada.	Cold	1.0002	—
130	Bumpass Hell, Mt. Lassen Park. .	26.3°	1.0056	6.8
135	Sulphur Works, Mt. Lassen Park.	32.6°	1.0034	7.4

Laccophilus mexicanus Aubé.

Number	Locality	Temperature	Specific Gravity	pH
102	Darrough's Hot Springs, Nevada	40.2°	1.0025	9.0
104	Monte Cristo, Nevada	38.3°	1.0052	8.7
113	Soldier Meadows, Nevada	19.2°	1.0007	8.8
118	Denio, Oregon	39.0°	1.0030	8.4
120b	Cedarville, California	36.2°	1.0034	8.2

This species would appear to extend its range northward in thermal waters through Nevada as the last locality is in the extreme eastern part of California. Two of the records indicate rather high temperatures.

Laccophilus decipiens Lec.

Six records of this species are all from springs of moderate temperature and alkalinity, quite similar to one noted previously ('28, Brues).

Number	Locality	Temperature	Specific Gravity	pH
96	Monte Neva, Nevada	36.3°	1.0038	8.4
97	Sunnyside, Nevada	30.8°	1.0029	9.3
104	Monte Christo, Nevada	38.3°	1.0037	8.4
108	Gerlach, Nevada	36.3°	1.0061	7.5
121	Kelly Hot Springs, California	38.5°	1.0032	8.4
122	Bassett's Hot Springs, California	39.5°	1.0037	8.4

Hydrovatus brevipes Sharp.

A single record is from Cedarville, California in hot spring No. 120b in water of 36.2°, specific gravity, 1.0034, pH 8.2.

Bidessus affinis Say.

In addition to four previous records (Brues '28) twelve may now be added for this widespread form. The temperatures range up to 41°, but nearly all fall below 39°, in alkaline water from pH 7.7 to 9.6 +. The salinities range up to 1.0150.

Number	Locality	Temperature	Specific Gravity	pH
66	Firehole River, Yellowstone Park.	38.4°	1.0024	8.9
69	Shoshone Basin, Yellowstone Park	31.2°	1.0036	8.2
72	Shoshone Basin, Yellowstone Park	34.5°	1.0062	7.7
78	Biscuit Basin, Yellowstone Park..	35.0°	1.0040	9.6+
80	Firehole Pool, Yellowstone Park..	36.0°	1.0046	8.2
93	Preston, Idaho..................	36.0°	1.0150	8.0
94	Cherry Creek, Nevada..........	—	1.0038	8.4
95	Cherry Creek, Nevada..........	36.3°	1.0043	8.4
113	Soldier Meadows, Nevada........	19.2°	1.0007	8.8
114	Hausen, California..............	36.2°	1.0033	7.5
120b	Cedarville, California...........	36.2°	1.0034	8.2
121	Kelly Hot Springs, California....	38.5°	1.0032	8.4

Cœlambus lutescens Lec.

Six springs yielded specimens of this species in addition to an atypical example from hot spring No. 77 which is probably the same. They all come from noticeably alkaline water (pH 8.3–9.5), only one record indicating a temperature of more than 40°. One previous record obtained in 1927 is from Denio, Oregon in hot spring No. 16 at 39°.

Number	Locality	Temperature	Specific Gravity	pH
77	Lower Geyser Basin, Yell. Park ..	33.9°	1.0056	9.5
96	Monte Neva, Nevada...........	36.3°	1.0038	8.4
97	Sunnyside, Nevada.............	30.8°	1.0029	9.3
100	Antelope Valley, Nevada........	35.8°	1.0038	9.1
103	Cortez, Nevada.................	40.8°	1.0041	8.5
118	Denio, Oregon..................	39.0°	1.0030	8.4
150	Paoha Isl., Mono Lake, Calif.....	32.0°	1.0045	8.3

Cœlambus nigrescens Fall.

This species was taken only once, in company with the preceding one at Denio, Oregon at 39.0°.

Cœlambus impressopunctatus Sch.

Collected only at Hausen, California in hot spring No. 114; temperature 36.2°, specific gravity 1.0033, pH 7.5.

Cœlambus sp. (near *artus* Fall).

A single hot spring locality is in spring No. 69 in the Shoshone Geyser Basin, Yellowstone Park in water at 31.2°, specific gravity, 1.0036, pH 8.2.

Cœlambus collatus Fall.

This form was taken at two places in northwestern Nevada.

Number	Locality	Temperature	Specific Gravity	pH
108	Gerlach, Nevada	36.3°	1.0061	7.5
113	Soldier Meadows, Nevada	19.2°	1.0007	8.8

Cœlambus fastidiosus Fall.

One series from the Pinnacles, Pyramid Lake, Nevada in hot spring No. 106a at 39.0°, specific gravity, 1.0064, pH 8.4.

Cœlambus compar Fall (?).

One series from the White Arrow Sanitarium Springs near Blanche, Idaho, in hot spring No. 86 in water at 39.0°, sp. gr. 1.0040, pH 8.6.

Cœlambus sp.

Females of an undetermined species were taken at two localities, one at the very high temperature of 44.5°.

Number	Locality	Temperature	Specific Gravity	pH
103	Cortez, Nevada	44.5°	1.0041	8.5
120b	Cedarville, California	28.4°	1.0034	8.2

Cœlambus sp.

Another undetermined species is represented in two collections.

Number	Locality	Temperature	Specific Gravity	pH
113	Soldier Meadows, Nevada	19.2°	1.0007	8.8
121	Kelly Hot Springs, California	39.5°	1.0032	8.4

Cœlambus sellatus Lec.

A single series of this species was taken in hot spring No. 77 in the Lower Geyser Basin, Yellowstone in water at 33.9°, sp. gr. 1.0056, pH 9.5.

Cœlambus thermarum Darlington.

This species, which was described from material collected by us in two Nevada hot springs in 1927 appears in the collections from three more springs as follows:

Number	Locality	Temperature	Specific Gravity	pH
20	Winnemucca, Nevada	38.0°	1.0014	8.6
23a	Watt's Ranch, Nevada	30.0°	1.0021	8.6
103	Cortez, Nevada	44.5°	1.0041	8.5
113	Soldier Meadows, Nevada	19.2°	1.0007	8.8
120b	Cedarville, California	28.4°	1.0034	8.2

It will be noted that the temperature record from one spring is unusually high and that the pH range, at least as here indicated, is not wide.

Agabus griseipennis Lec.

Two records for this species were obtained, in addition to two others previously noted ('28). These indicate the occurrence of this form quite generally in very warm water.

Number	Locality	Temperature	Specific Gravity	pH
16	Denio, Oregon	39.0°	1.0015	8.5
23a	Watt's Ranch, Nevada	36.0°	1.0021	8.5
87	Mountain Home, Idaho	42.4°	1.0027	9.6+
96	Monte Neva, Idaho	36.3°	1.0038	8.4

Agabus lutosus Lec.

A single specimen was taken in hot spring No. 130 at Bumpass Hell, Mt. Lassen Park in water at 26.3°, sp. gr. 1.0056, pH 6.8.

Agabus obliteratus Lec.

One series from the Shoshone Geyser Basin, Yellowstone Park, hot spring No. 69. They were taken at 31.7° in water with a specific gravity of 1.0036 and pH of 8.2.

Agabus seriatus Say.

Two hot springs of widely different reaction yielded specimens of this species.

Number	Locality	Temperature	Specific Gravity	pH
86	White Arrow Springs, Idaho	41.0°	1.0040	8.6
124	Mt. Lassen Park	30.6°	1.0037	3.6−

Rhantus binotatus Harris.

This widely distributed species appears in two series from hot springs, at moderate temperatures.

Number	Locality	Temperature	Specific Gravity	pH
95	Cherry Creek, Nevada	30.4°	1.0043	8.4
96	Monte Neva, Nevada	36.3°	1.0038	8.4

HYDROPHILIDÆ.

Ochthebius bruesi Darlington.

This species was described from material collected by us in 1927, and appears in series from four more hot springs in the present collections. All are from moderately or highly alkaline waters in several cases at quite high temperatures.

Number	Locality	Temperature	Specific Gravity	pH
24	Beowawe, Nevada	38.8°	1.0020	9.6
103	Cortez, Nevada	40.8°	1.0041	8.5
113	Soldier Meadows, Nevada	19.2°	1.0007	8.8
120a	Cedarville, California	43.0°	1.0037	8.2
120b	Cedarville, California	36.2°	1.0034	8.2

Ochthebius rectus Lec.

Two localities are represented.

Number	Locality	Temperature	Specific Gravity	pH
120b	Cedarville, California	36.2°	1.0034	8.2
121	Kelly Hot Springs, California	39.5°	1.0032	8.4

Ochthebius lineatus Lec.

One specimen of this species was taken in Fish Springs, California (hot spring No. 147) at a temperature of 32.2°, sp. gr. 1.0060, pH 7.7.

Ochthebius interruptus Lec.

To a previous record from Wells, Nevada may be added Cortez, Nevada (hot spring No. 103 at 44.5°, sp. gr. 1.0041, pH 8.5).

Helophorus oblongus Lec.

Number	Locality	Temperature	Specific Gravity	pH
47b	Indian Pond, Yellowstone Park	Cold	1.0001	—

Helophorus lecontei Knisch.

Number	Locality	Temperature	Specific Gravity	pH
96	Monte Neva, Nevada...........	36.3°	1.0038	8.4
120b	Cedarville, California...........	36.2°	1.0034	8.2

Helophorus obscurus Lec.

Number	Locality	Temperature	Specific Gravity	pH
96	Monte Neva, Nevada...........	36.3°	1.0038	8.4
102	Darrough's Hot Springs, Nevada	36.8°	1.0025	9.0
120b	Cedarville, California............	36.2°	1.0034	8.2

Helophorus lineatus Say.

Number	Locality	Temperature	Specific Gravity	pH
89	Indian Springs, Idaho...........	33.2°	1.0031	8.4
91	Cleveland, Idaho..............	28.2°	1.0062	7.5
93	Preston, Idaho.................	36.0°	1.0150	8.0
94	Cherry Creek, Nevada..........	—	1.0038	8.4
95	Cherry Creek, Nevada..........	36.3°	1.0043	8.4
96	Monte Neva, Nevada...........	36.3°	1.0038	8.4
101	Birch Creek Ranch, Nevada.....	36.2°	1.0038	7.3
102	Darrough's Hot Springs, Nev.....	36.8°	1.0025	9.0
103	Cortez, Nevada................	40.8°	1.0041	8.5
104	Monte Christo, Nevada..........	38.3°	1.0052	8.7

Tropisternus dorsalis Brulle.

With four previous records (Brues '28) and five in the present collections, this species has now been taken in nine hot springs at temperatures up to 42.2° and between pH limits of 7.5–8.6 and always in water of low salinity (1.0012 to 1.0041).

Number	Locality	Temperature	Specific Gravity	pH
96	Monte Neva, Nevada	36.3°	1.0038	8.4
103	Cortez, Nevada	40.8°	1.0041	8.5
118	Denio, Oregon	42.2°	1.0030	8.4
121	Kelly Hot Springs, Calif.	39.3°	1.0032	8.4
122	Bassett's Hot Springs, Calif	39.5°	1.0037	8.4

Tropisternus ellipticus Lec.

Two more records (four in all) show this species to have a distribution similar to that of *T. dorsalis*.

Number	Locality	Temperature	Specific Gravity	pH
113	Soldier Meadows, Nevada	19.2°	1.0007	8.8
143	Paraiso Hot Springs, Calif.	33.4°	1.0042	7.4

Tropisternus californicus Lec.

This species appeared at seven localities although we had taken it only twice before, in the Yellowstone and near Battle Mountain, Nevada. It was taken in more acid and more alkaline water than the two preceding forms and in more saline water, ranging from pH 6.5 to 9.1 and sp. gr. 1.0007 to 1.0062.

Number	Locality	Temperature	Specific Gravity	pH
46b	Bijah Spring, Yellowstone Park	34.3°	1.0036	6.3
86	White Arrow Springs, Idaho	41.0°	1.0040	8.6
91	Cleveland, Idaho	28.2°	1.0062	7.5
96	Monte Neva, Nevada	36.3°	1.0038	8.4
100	Antelope Valley, Nevada	35.8°	1.0032	9.1
103	Cortez, Nevada	40.8°	1.0041	8.5
113	Soldier Meadows, Nevada	19.2°	1.0007	8.8

Tropisternus sublævis Lec.

We had not taken this species in hot springs before, but the present series includes eleven different localities scattered over a wide area. Several records are from water at more than 40°; the pH range is wide extending from 6.8 to 9.6 +, and in only one case does the salinity exceed 1.0048.

Number	Locality	Temperature	Specific Gravity	pH
38	West Thumb, Yellowstone Park..	36.2°	1.0025	6.8
61	Soda Spring, Yellowstone Park...	29.0°	1.0048	6.9
69	Shoshone Basin, Yellowstone Park	31.2°	1.0036	8.2
86	White Arrow Springs, Idaho.....	41.0°	1.0040	8.6
87	Mountain Home, Idaho.........	42.4°	1.0027	9.6+
91	Cleveland, Idaho...............	28.2°	1.0062	7.5
96	Monte Neva, Nevada...........	36.3°	1.0038	8.4
102	Darrough's Hot Springs, Nevada..	36.8°	1.0025	9.0
103	Cortez, Nevada................	40.8°	1.0041	8.5
113	Soldier Meadows, Nevada........	19.2°	1.0007	8.8
120b	Cedarville, California...........	36.2°	1.0034	8.2

Hydrous triangularis Say.

This familiar large species was only taken once alive, although we have seen it on several occasions floating dead on the surface of very hot water which it had attempted to enter. The specimen came from water at 36.8° in hot spring No. 118 near Denio, Oregon.

Paracymus subcupreus Say.

To four previous records we are now able to add twenty-four additional ones. They indicate its occurrence in salinities varying from 1.0025 to 1.0047 and at hydrogen ion concentrations from pH 6.4 to 9.6 +. Eight records of over 40° indicate that it may inhabit extremely warm water.

Number	Locality	Temperature	Specific Gravity	pH
45	Norris Geyser Basin, Yell. Pk. ...	44.8°	1.0040	7.9
65	Firehole River, Yellowstone Park.	33.2°	—	—
67	Firehole River, Yellowstone Park.	36.2°	1.0044	8.2
71	Shoshone Basin, Yellowstone Park	40.8°	1.0046	8.8
72	Shoshone Basin, Yellowstone Park	35.4°	1.0062	7.7
74	Shoshone Basin, Yellowstone Park	35.3°	1.0047	6.4
86	White Arrow Springs, Idaho......	39.0°	1.0040	8.6
87	Mountain Home, Idaho..........	35.5°	1.0027	9.6+
91	Cleveland, Idaho...............	28.2°	1.0062	7.5
97	Sunnyside, Nevada.............	30.8°	1.0029	9.3
98	Sunnyside, Nevada.............	33.6°	1.0042	8.3
99	Duckwater, Nevada.............	29.0°	1.0032	8.0
100	Antelope Valley, Nevada.........	35.8°	1.0032	9.1
102	Darrough's Hot Springs, Nevada..	36.8°	1.0025	9.0
103	Cortez, Nevada................	40.8°	1.0041	8.5
104	Monte Cristo, Nevada..........	38.3°	1.0052	8.7
114	Hausen, Calif..................	36.2°	1.0033	7.5
115	Surprise Valley, Calif...........	34.2°	1.0027	8.3
116	Surprise Valley, Calif...........	40.2°	1.0035	7.6
118	Denio, Oregon.................	39.0°	1.0030	8.4
120a	Cedarville, Calif...............	43.0°	1.0037	8.2
120b	Cedarville, Calif...............	36.2°	1.0034	8.2
121	Kelly Hot Springs, Calif.........	38.5°	1.0032	8.4
141	Calistoga, Calif................	42.8°	1.0035	8.4

Paracymus elegans Fall.

This small species was taken once in a hot spring in the Kern River valley in California at Democrat Springs in water of rather low temperature (30.2°), sp. gr. 1.0017, pH 7.4.

Chasmogenus normatus Lec.

Four localities yielded specimens of this species, only one in water above 40° and all in water of nearly neutral reaction (7.3–7.4). All are in California.

Number	Locality	Temperature	Specific Gravity	pH
123a	Henderson, Calif.	37.6°	1.0040	7.4
140	Seigler Hot Springs, Calif.	42.8°	1.0057	7.3
143	Paraiso Hot Springs, Calif.	33.4°	1.0042	7.4
148	Democrat Hot Springs, Calif.	24.8°	1.0017	7.4

Enochrus (*Philhydrus*) **carinatus** Lec.

All but one of five localities are in Yellowstone Park. The species occurs in quite saline water and only, so far as our records extend in rather strongly alkaline water.

Number	Locality	Temperature	Specific Gravity	pH
60a	Angel Terrace, Yellowstone Park	37.6°	1.0040	8.3
84	Near Spasmodic Geyser, Yell. Pk.	32.0°	1.0032	9.3
102	Darrough's Hot Springs, Nev.	36.8°	1.0025	9.0
106a	Pinnacles, Pyramid Lake, Calif.	29.0°	1.0064	8.4
107	Pinnacles, Pyramid Lake, Calif.	36.5°	1.0074	8.4

Enochrus conjunctus Fall.

Nineteen records were obtained for this species indicating a wide range of tolerance to varying salinity, hydrogen ion concentration and temperature, although only two series came from water above 40° and none above 41°.

Number	Locality	Temperature	Specific Gravity	pH
46a	Bijah Spring, Yellowstone Park..	39.3°	1.0039	6.5
50	Mary Bay, Yellowstone Park.....	40.1°	1.0022	7.3
53	Turbid Lake, Yellowstone Park..	34.0°	1.0034	3.6
67	Firehole River, Yellowstone Park.	36.2°	1.0044	8.2
69	Shoshone Basin, Yellowstone Park	31.2°	1.0036	8.2
84	Near Spasmodic Geyser, Yell. Pk.	32.0°	1.0032	9.3
91	Cleveland, Idaho...............	28.2°	1.0062	7.5
102	Darrough's Hot Springs, Nev.....	36.8°	1.0025	9.0
103	Cortez, Nev....................	40.8°	1.0041	8.5
108	Gerlach, Nev...................	32.8°	1.0061	7.5
120a	Cedarville, California............	36.2°	1.0037	8.2
121	Kelly's Hot Springs, Calif........	38.5°	1.0032	8.4
124	Mt. Lassen Park, Calif...........	30.6°	1.0037	3.6−
126	Mt. Lassen Park, Calif...........	31.2°	1.0025	7.1
127	Bumpass Hell, Mt. Lassen Park..	33.5°	1.0028	6.0
128	Bumpass Hell, Mt. Lassen Park..	34.2°	1.0028	6.7
130	Bumpass Hell, Mt. Lassen Park..	35.6°	1.0056	6.8
131	Bumpass Hell, Mt. Lassen Park..	34.2°	—	—
150	Paoha Isl., Mono Lake, Calif.....	32.8°	1.0045	8.3

Enochrus pectoralis Lec.

Number	Locality	Temperature	Specific Gravity	pH
143	Paraiso Hot Springs, Calif.......	33.4°	1.0042	7.4

Enochrus nebulosus Say.

Nine series of this species were obtained in addition to eleven previously noted (Brues '28). As will be seen from the data given below this form seems to be restricted to water of alkaline reaction (pH 7.4–9.6 +) and ranges into water slightly above 40°.

Number	Locality	Temperature	Specific Gravity	pH
67	Firehole River, Yellowstone Park	35.5°	1.0027	9.6+
77	Lower Geyser Basin, Yell. Pk.	33.9°	1.0056	9.5
87	Mountain Home, Idaho	35.5°	1.0027	9.6+
91	Cleveland, Idaho	28.2°	1.0062	7.5
99	Duckwater, Nevada	29.0°	1.0032	8.0
100	Antelope Valley, Nevada	39.2°	1.0032	9.1
103	Cortez, Nevada	40.8°	1.0041	8.5
121	Kelly Hot Springs, Calif.	38.5°	1.0032	8.4
143	Paraiso Hot Springs	33.4°	1.0042	7.4

Enochrus nigrellus Sharp.

Number	Locality	Temperature	Specific Gravity	pH
143	Paraiso Hot Springs, Calif.	33.4°	1.0042	7.4

Cimbiodyta dorsalis Mots.

This southern Californian species was taken twice, one record indicating a quite considerable northern extension of its range.

Number	Locality	Temperature	Specific Gravity	pH
113	Soldier Meadows, Nevada	19.2°	1.0007	8.8
143	Paraiso Hot Springs, Calif.	33.4°	1.0042	7.4

Laccobius agilis Rand.

Number	Locality	Temperature	Specific Gravity	pH
40	West Thumb, Yellowstone Park..	37.0°	1.0058	7.3
49	Squaw Lake, Yellowstone Park...	38.5°	1.0051	7.2
50	Mary Bay, Yellowstone Park....	38.3°	1.0022	7.3
54	Turbid Lake, Yellowstone Park ..	23.4°	1.0021	8.6
55	Turbid Lake, Yellowstone Park ..	36.8°	1.0066	7.3
56	Turbid Lake, Yellowstone Park ..	40.6°	1.0040	7.2
60a	Angel Terrace, Yellowstone Park	38.0°	1.0040	8.3
60b	Highland Terrace, Yell. Park.....	37.6°	—	—
61	Soda Spring, Yellowstone Park...	29.0°	1.0048	6.9
68	Shoshone Basin, Yellowstone Park	41.8°	1.0040	9.4
70	Shoshone Basin, Yellowstone Park	31.0°	1.0042	9.0
72	Shoshone Basin, Yellowstone Park	35.4°	1.0062	7.7
75	Three Sisters, Yellowstone Park ..	37.2°	1.0046	9.1
78	Biscuit Basin, Yellowstone Park..	35.0°	1.0040	9.6+
79	Sprite Pool, Yellowstone Park....	36.3°	1.0039	8.9
80	Firehole Pool, Yellowstone Park..	36.0°	1.0046	8.2
84	Spasmodic Geyser, Yell. Pk......	32.0°	1.0032	9.3
92	Cleveland, Idaho..............	39.1°	1.0067	8.1
96	Monte Neva, Nevada...........	36.3°	1.0038	8.4
98	Sunnyside, Nevada.............	33.6°	1.0042	8.3
101	Birch Creek Ranch, Nevada.....	36.2°	1.0038	7.3
103	Cortez, Nevada.................	40.8°	1.0041	8.5
113	Soldier Meadows, Nevada.......	19.2°	1.0007	8.8
150	Paoha Isl., Mono Lake, Calif.....	32.8°	1.0045	8.3

Laccobius piceus, var.

Number	Locality	Temperature	Specific Gravity	pH
37	West Thumb, Yellowstone Park..	Cool	1.0056	8.9
57a	Tower Junction, Yellowstone Park	40.2°	1.0057	7.0
58	Whirligig Geyser, Yell. Park.....	38.2°	1.0051	3.6
77	Lower Geyser Basin, Yell. Park..	33.9°	1.0056	9.5
80	Firehole Pool, Yellowstone Park.	36.0°	1.0046	8.2
84	Spasmodic Geyser, Yell. Park..	32.0°	1.0032	9.3
150	Paoha Isl., Mono Lake, Calif..	32.8°	1.0045	8.3

Laccobius bruesi Winters

Number	Locality	Temperature	Specific Gravity	pH
121	Kelly Springs, Canby, Calif......	39.5°	1.0032	8.4
137	Wilbur Hot Springs, Calif........	32.8°	1.0150	8.5

Laccobius ellipticus Lec.

Number	Locality	Temperature	Specific Gravity	pH
86	Blanche, Idaho..................	39.0°	1.0040	8.6
105	Pyramid Lake, Nevada..........	29.8°	1.0064	8.0
106a	Pyramid Lake, Nevada..........	29.0°	—	8.4
150	Paoha Isl., Mono Lake, Calif.....	32.8°	1.0036	7.3

Cercyon sp.

Number	Locality	Temperature	Specific Gravity	pH
55	Turbid Lake, Yellowstone Park ..	36.0°	1.0066	7.3

HETEROCERIDÆ.

Heterocerus sp.

Number	Locality	Temperature	Specific Gravity	pH
91	Cleveland, Idaho................	41.2°	1.0062	7.5
93	Preston, Idaho..................	36.0°	1.0150	8.0
102	Darrough's Hot Springs, Nevada	36.8°	1.0025	9.0
150	Paoha Isl., Mono Lake, Calif.....	40.8°	1.0045	8.3

Heterocerus collaris Kies.

Number	Locality	Temperature	Specific Gravity	pH
99	Duckwater, Nevada	29.0°	1.0032	8.0

Heterocerus brunneus Mels.

Number	Locality	Temperature	Specific Gravity	pH
99	Duckwater, Nevada	29.0°	1.0032	8.0
103	Cortez, Nevada	40.8°	1.0041	8.5

Coleopterous Larvæ.

Cicindelidae.

Certain hot springs, especially those where there is much soft clayey deposit about their borders, harbor in this warm soil the larvæ of cicindelid beetles which seem to thrive in the burrows which they excavate often very close to the water. I have previously reported the occurrence of these larvæ in such situations and we secured additional material in about five hot springs during 1930. It is impossible to identify the larvæ specifically, but adults taken flying in these localities indicate that they are the same species previously noted (Brues '28, p. 180) and also in addition *Cicindela latesignata* Lec., var. *obliviosa* Casey, previously known from Southern California, but taken by us much farther north about hot spring No. 120b at Cedarville, Calif. and no doubt representing a northward extension of this form in connection with hot springs. Other collections of Cicindelid larvæ are from the warm soil about the following springs: Nos. 40, 67, 126, 131, and 150.

Dytiscidae.

Our collections of dytiscid larvæ are much less numerous than might be expected from the large series of adult beetles obtained. They appear to represent four genera as nearly as I have been able

to place them with the use of Wilson's account ('23) and the recent keys of Needham ('27).

Dytiscus sp.

One large larva from hot spring No. 47b (Indian Pond, Yellowstone Park) is without question a larva of some species of Dytiscus, perhaps *D. marginicollis* Lec., a species that I obtained previously in hot spring No. 23 near Battle Mountain, Nevada. In both cases, the water was very slightly saline (1.0001 and 1.0008).

Cybister sp.

In hot spring No. 113 near Gerlach, Nevada we collected a larva of Cybister agreeing closely with Wilson's description and figures of *C. fimbriolatus* Say. We had previously taken an adult of this genus in hot spring No. 21 at Sou Hot Springs, Nevada, but found no adults on the last trip.

Laccophilus sp.

Four springs yielded specimens of larvæ belonging to this genus. The records are as follows:

Number	Locality	Temperature	Specific Gravity	pH
91	Cleveland, Idaho	38.0°	1.0062	7.5
100	Antelope Valley, Nev.	39.2°	1.0032	9.1
101	Birch Creek, Nev.	36.2°	1.0038	7.3
121	Canby, California	38.5°	1.0032	8.4

It is probable that the last, from Kelly Hot Springs, Canby, California is *L. decipiens*, as we obtained adults of that species there.

Bidessus or **Cœlambus**.

Four series of larvæ were obtained that run to Hydroporus in the keys, but as the most closely related adults found were members of Cœlambus and Bidessus it is probable that they belong to one of these genera, probably the latter as one of the springs containing these larvæ (No. 66) yielded specimens of *Bidessus affinis*.

Number	Locality	Temperature	Specific Gravity	pH
63	Amphitheatre Springs, Yell. Pk...	27.4°	1.0043	3.6
66	Firehole River, Yell. Pk..........	38.4°	1.0024	8.9
67	Firehole River, Yell. Pk..........	36.2°	1.0044	8.2
75	Three Sisters, Yell. Pk...........	34.0°	1.0046	9.1

Hydrophilidae.

Tropisternus.

Larvæ of this genus were collected in thirteen of the hot springs visited during 1930, as follows:

Number	Locality	Temperature	Specific Gravity	pH
38	West Thumb, Yellowstone Park..	34.2°	1.0025	6.8
44	Lewis Lake, Yellowstone Park....	30.8°	1.0023	7.8
47a	Indian Pond, Yellowstone Park...	Cool	1.0001	7.1
65	Firehole River, Yellowstone Park.	33.2°	—	8.3
66	Firehole River, Yellowstone Park.	38.4°	1.0024	8.9
67	Firehole River, Yellowstone Park.	36.2°	1.0044	8.2
68	Shoshone Basin, Yellowstone Park	39.2°	1.0040	9.4
69	Shoshone Basin, Yellowstone Park	31.2°	1.0036	8.2
77	Lower Geyser Basin, Yell. Pk.....	38.6°	1.0056	9.5
91	Cleveland, Idaho...............	41.2°	1.0062	7.5
102	Darrough's Hot Spring, Nev.	36.5°	1.0025	9.0
113	Gerlach, Nev...................	19.2°	1.0007	8.8
149	Democrat Springs, California.....	31.4°	1.0047	8.7

Enochrus.

Three localities yielded larvæ of this genus as follows:

Number	Locality	Temperature	Specific Gravity	pH
50	Mary Bay, Yellowstone Park.....	38.3°	1.0022	7.3
67	Firehole River, Yellowstone Park.	36.2°	1.0044	8.2
126	Mt. Lassen National Park.......	31.2°	1.0025	7.1

Helmis.

Larvæ, presumably *H. similis* or allied were numerous in hot spring No. 89 at Indian Springs, Idaho, where numerous adult beetles of this species were collected. Others were taken in No. 57a at Tower Junction, Yellowstone Park.

MOLLUSCA.

A considerable series of molluscs is contained in the material collected. Through the great kindness of my good friend, W. J. Clench, of the Museum of Comparative Zoölogy, I am enabled to report on the several species, for which he has given me authoritative determinations.

In all, members of nine families are represented, all of them gastropods, except a single lot of Sphærium. In a few cases it has not been possible to give specific names at present, especially for certain lots of Physa, as well as for an Amnicola and a Lymnæa from hot spring No. 99, at Duckwater, Nevada, which are probably undescribed.

Succineidæ.

Succinea rusticana Gould.

Number	Locality	Temperature	Specific Gravity	pH
103	Cortez, Nevada	40.8°	1.0041	8.5
114	Hausen, California	36.2°	1.0033	7.5
115	Surprise Valley, Nevada	34.2°	1.0027	8.3
116	Surprise Valley, Nevada	40.2°	1.0035	7.6

This species appears to frequent only water of slight alkalinity, but extends into water of quite high temperature.

Lymnæidæ.

Lymnæa palustris haydeni Lea.

Number	Locality	Temperature	Specific Gravity	pH
51	Mary Bay, Yellowstone Park	38.5°	1.0022	7.3
54	Turbid Lake, Yellowstone Park	23.4°	1.0021	8.6

This is the same species taken by us previously near the first of the localities cited above. It does not appear to occur at high temperatures nor in highly alkaline nor in acid waters.

Lymnæa sp. (probably undescribed).

Number	Locality	Temperature	Specific Gravity	pH
99	Duckwater, Nevada.	29.0°	1.0032	8.0

LANCIDÆ.

Lanx patelloides Lea.

Taken at Big Bend Hot Springs near Henderson, California (hot spring No. 123b), in water at 39.5°, specific gravity 1.0043, pH 7.4.

PLANORBIDÆ.

Three lots of Planorbis are all from only moderately warm, alkaline water.

Planorbis antrosus Conrad.

Taken in hot spring No. 111 near Gerlach, Nevada, at 33.7°, specific gravity 1.0042, pH 8.7.

This species occurs also in strongly brackish estuarine water.

Planorbis subcrenatus.

Taken in hot spring No. 98 at Sunnyside, Nevada, at 33.6°, specific gravity 1.0043, pH 8.3.

Planorbis sp.

An unidentified species was taken in hot spring No. 97, near Sunnyside, Nevada, at 30.8°, specific gravity 1.0029, pH 9.3.

PARAPHOLIGIDÆ.

Two forms of Parapholyx are included in our collections: *P. effusa* Lea from Big Bend Hot Springs, Henderson, California, in water of specific gravity 1.0043, pH 7.4 at 39.5°, and *P. effusa*, var. *costata* Stearns from Pyramid Lake, Nevada, in hot spring No. 105 in water at 32.0° with a specific gravity of 1.0064 and pH of 8.0.

Physidæ.

More series of this family than of any other were taken as Physa seems to be the dominate type in thermal waters.

Physa osculans Hald.

Number	Locality	Temperature	Specific Gravity	pH
145	Jacumba Hot Springs, Calif.	23.0°	1.0041	7.4

Physa johnsoni Clench.

I have received some specimens of this species which were collected by Mr. D. J. Zinn in a hot spring at Banff, Alberta, Canada. This is the type locality.

Physa propinqua Tryon.

Number	Locality	Temperature	Specific Gravity	pH
90	Lava Hot Springs, Idaho	40°	1.0053	—

Physa spp.

The following records refer to species not yet specifically determined. Spring No. 98 yielded two species.

Number	Locality	Temperature	Specific Gravity	pH
51	Mary Bay, Yellowstone Park	38.5°	1.0038	—
81	Tangle Creek, Yellowstone Park	32.8°	1.0037	8.4
89	Indian Springs, Idaho	31.6°	1.0031	8.4
91	Cleveland, Idaho	32.8°	1.0062	7.5
92	Cleveland, Idaho	39.1°	1.0067	8.1
97	Sunnyside, Nevada	30.8°	1.0029	9.3
98	Sunnyside, Nevada (two species)	33.6°	1.0042	8.3
123a	Henderson, California	39.5°	1.0043	7.4
144	Paso Robles, California	32.4°	1.0051	7.4
146	Fish Springs, California	30.0°	1.0058	7.4
150	Paoha Isl., Mono Lake, Calif.	32.8°	1.0045	8.3

PLEUROCERIDÆ.

Goniobasis nigrina Lea.

Number	Locality	Temperature	Specific Gravity	pH
123b	Henderson, California	39.5°	1.0043	7.4

Goniobasis placifera Lea.

Number	Locality	Temperature	Specific Gravity	pH
123b	Henderson, California	39.5°	1.0043	7.4

AMNICOLIDÆ.

Fluminicola nevadensis Walker.

Number	Locality	Temperature	Specific Gravity	pH
98	Sunnyside, Nevada	33.6°	1.0042	8.3
111	Gerlach, Nevada	32.2°	1.0042	8.7

Fluminicola seminalis Hinds.

Number	Locality	Temperature	Specific Gravity	pH
123b	Henderson, California	39.5°	1.0043	7.4

Fluminicola sp.

Many young specimens of an undetermined species of Fluminicola were taken in hot spring No. 89, at Indian Springs, Idaho (specific gravity 1.0031, pH 8.4).

Pyrgalopsis nevadensis Stearns.

One series comes from the Pinnacles at the northern end of Pyramid Lake, Nevada (hot spring No. 105; specific gravity 1.0064, pH 8.0).

Amnicola sp. (probably undescribed).

A single locality, hot spring No. 99, at Duckwater, Nevada, yielded specimens of Amnicola. The water has a specific gravity of 1.0032 and pH of 8.0 with a temperature of 29.0°.

SPHÆRIDÆ.

A single series of an unidentified species of Sphærium represents the only pelecypod mollusc obtained. They came from Henderson, California, where they were taken together with a variety of other molluscs in hot spring No. 123b in water at 39.5°; specific gravity 1.0043 and pH 7.4.

It may be said of the entire collection of molluscs that none occur in very hot water as none have been taken at temperatures above 40.8°, and that their range with reference to hydrogen ion concentration is not greatly limited as they extend over a pH range of from 7.2 to 9.6 or over. This statement is made to include also a consideration of the data which we have previously collected (Brues '28) in the same general region.

Since my previous account was published two papers dealing with the occurrence of molluscs in brackish waters have appeared which are of interest here as they relate to the extension of fresh water species into brackish water. Richards ('29) has found that *Physa heterostropha* may be rapidly acclimatized to considerable salinities produced by the addition of sea water to the fresh water medium in which this species occurs. He added sea water at short intervals of a few days, producing consecutively mixtures containing 5%, 10%, 15%, etc., of sea water and these did not interfere with the activity and apparent health of the snails, at least in the weaker dilutions of 20–25% and less. These salinities are well above the concentrations encountered in thermal waters. He found the same conditions to prevail with two other common pond snails, *Lymnæa stagnalis appressa* and *L. palustris*, which could stand approximately the same concentrations of sea water ('29a). It thus appears that in the case of certain fresh water snails at least, the salinities present commonly in thermal waters are no barrier. Both of these genera have of course already been found in hot springs, Physa the most abundantly.

On the basis of field observations on the same *Physa heterostropha*, Bailey ('29) reports the occurrence of this species in brackish water with 50% of ocean concentration in Chesapeake Bay, together with *Goniobasis virginica* and *Congeria leucopheata*, the latter almost exclusively a brackish water form. The same observer records two other snails, *Amnicola limosa* and *Planorbis antrosus* in the bay water at 30% ocean concentration.

FISHES.

Only a few of the springs we visited were found to contain fish and none of these were living in water of high temperature. However, one form collected proved to be an extremely interesting type which has been described by Dr. Carl L. Hubbs who has also been so kind as to identify the few other specimens that we collected.

Two of the species are not native to the places where we obtained them. The first of these were numerous goldfish which were reared in one of the pools at hot spring No. 89 at Indian Springs, Idaho. These fish were living at 33.7° in water of moderate salinity (1.0031) and slight alkalinity (pH 8.4). The other introduced species is *Gambusia patruelis*, var. *holbrookii*, an Atlantic coast form which has been introduced into the west as an enemy of mosquito larvæ. It was present in hot spring No. 147 at Fish Springs in the Imperial Valley, California, in water at 30°, specific gravity 1.0058 and pH 7.4. In this spring we obtained larvæ of *Anopheles pseudopunctipennis* Theob.

Siphateles oregonensis Snyder ?

In hot spring No. 68b, 16 miles northwest of Gerlach, Nevada. Dr. Hubbs informs me that this chub falls within the limits of *S. obesus*, a species occurring in the Lahontan Basin, but that it agrees better with *S. oregonensis* that occurs in certain isolated Oregon Lakes. As this locality is near the Oregon border it seems probable that the fish reached there from Oregon, especially as this seems to be the case with frogs collected just north of the present place. The specimens were living in a large tule-bordered pool having a temperature of 33.7° in water of moderate salinity and alkalinity (1.0042; pH 8.7).

Apocope sp.

In hot spring No. 97 we found some young dace belonging to this genus. The water of this stream has a temperature of 30.8°,

and rather slight salinity (1.0029) but is strongly alkaline with a pH of 9.3.

Crenichthys nevadæ Hubbs.

The specimens which form the types for this genus are one of the most interesting taxonomic finds made during the course of our investigations. According to Dr. Hubbs ('32) Crenichthys is a very distinct generic type of cyprinodont fishes related to the genus Empetrichthys which is known only from an isolated locality in Death Valley, California. It is also similar to Orestias, a genus known only from lakes in the high Andes of South America, whence numerous species have been described. Contrasted with the Death Valley type, Crenichthys is herbivorous, suggesting long isolation and certainly giving evidence of protracted activity either on the part of the spring in which it now occurs or at least of those in the immediate neighborhood.

The type locality is spring No. 99, Duckwater, Nevada containing water with a salinity of 1.0032 and pH of 8.0 at a temperature of 31.8°. The spring has an extensive flow and the fish were collected by Mrs. Brues near its source in the small stream which extends for a short distance before it is dissipated in a flat swampy area.

Some recent work which is of interest in connection with the fish fauna of thermal water has been presented by Agersborg ('30). He records a number of freshwater fishes as living in the polluted overflow from a corn-products plant at Decatur, Illinois in water at a temperature of 29°. These fishes were Carp (*Cyprinus carpio* Linn.), Sunfish (*Lepomis miniatus* Jordan), Bluegill (*L. pallidus* Mitchell), Crappie (*Pomoxis annularis* Raf.), Catfish (*Amieurus natalis* Le Seur), Chub (*Erimyzon sucetta oblongus* Mitchill), Steel-colored Minnow (*Notropis whipplei* Girard), Shiner (*N. atherinoides* Raf.), Gizzard-shad (*Dorosoma cepedianum*). He has also investigated the effect of sudden change from warm water of 28°–30° to water near the freezing point with reference to certain species of freshwater fish. He finds that in the case of fish living in winter in water thus warmed with waste from the corn-products plant at Decatur, that when brought into the cold water they manifest oxygen hunger and continued exposure is fatal. The dissolved oxygen content of the warm water is slightly less than half that of the cold water and he attributes their respiratory difficulties to vaso-motor changes causing non-functioning of the gills. Even sudden slight changes from 28° to 24° produced unbalanced movements and from 26° to 20° resulted in sudden death.

On the basis of these reactions to changes of temperature it is easy to see why fish are so rarely encountered in hot springs, even those of moderate temperature, since under the topographic conditions usually prevailing in thermal waters the water temperature is by no means constant throughout the pools or streams fed by the springs.

AMPHIBIA.

A few collections made during 1930 contain amphibians, mainly tadpoles, taken in hot springs. The tadpoles have been identified by Dr. G. K. Noble of the American Museum of Natural History and the adult forms by Mr. Arthur Loveridge of the Museum of Comparative Zoölogy. As the result of this kind interest on the part of these two gentlemen, I am able to present the following account of our material.

Although the data we have been able to obtain are not extensive they show that several toads and frogs live successfully in thermal water of moderate temperature and salinity, but not so far as our observations go, do they occur in highly acid or alkaline water as our pH records extend only from 7.0 to 8.8.

Bufo woodhouseii Baird & Girard (?).

Tadpoles of this toad were taken at three localities in Yellowstone Park, two in strictly thermal water and one in the cool, practically non-saline water of Indian Pond.

Number	Locality	Temperature	Specific Gravity	pH
44	Lewis Lake, Yellowstone Park....	27.6°	1.0023	7.8
47	Indian Pond, Yellowstone Park...	Cool	1.0001	—
69	Shoshone Basin, Yellowstone Park	31.2°	1.0036	8.2

In both cases the temperature is rather low and the reaction of the water is very slightly alkaline. The identification of the tadpoles is not absolutely certain, but Dr. Noble tells me that they are unquestionably a species of Bufo, probably *B. woodhouseii.*

Bufo boreas halophilus Baird and Girard.

Tadpoles of this species were found in abundance in hot spring No. 135 near the Sulphur Works in Mt. Lassen National Park, Cali-

fornia in moderately saline (1.0034), very slightly alkaline (pH 7.4) water at 30.6°. This small stream flows rapidly along a rocky bed and is well supplied with algæ.

Adults of this species were observed commonly in Pyramid Lake which is quite noticeably saline. They may be seen swimming in the water at the edge of the lake which is practically devoid of shade or vegetation of any sort and most of their time, at least during the day must have to be spent in the water to avoid dessication. A number of individuals were seen also in damp niches just above water level on the massive pyramid of tufa which rises out of the body of the lake where they are washed by wave action which is considerable at all times in a lake of such large size. Due to the conditions prevailing here they appear to have become as highly aquatic as frogs. No frogs were seen in Pyramid Lake, however.

Bufo compactilis Wiegmann.

Adults of this species were taken in the seepage area of a water hole thirty miles north of Gerlach, Nevada in water evidently of thermal origin, but quite cool (19.2°; sp. gr. 1.0007; pH 8.8) together with three species of frogs. This spot which is isolated by miles of desert from the nearest permanent water has acquired a populous colony of amphibians.

Scaphiopus hammondii Baird.

Of the tadpoles listed here, Dr. Noble writes: "These tadpoles are certainly referable to Scaphiopus—the spadefoot toad—but they do not agree entirely with the published descriptions of *hammondii,* the only spadefoot toad known from this region. Their mouthparts are much nearer *S. couchii* which is not believed to occur in your locality. It is possible that *S. hammondii* exhibits much greater variation in tadpoles than we have hitherto believed." They were collected at Thermopolis, Wyoming in hot spring No. 35 in water of specific gravity 1.0056 and pH 7.9, at a temperature of 37°–38.4°. On being disturbed they would move into hotter parts of the pool as far as 45°, but soon returned to the cooler water as noted above. As the tadpoles were numerous, the species evidently breeds regularly in this spring.

Hyla regilla Baird and Girard.

This frog was previously collected by us in northern Nevada in hot spring No. 16 (Brues '28, p. 205) south of Denio, Oregon. In 1930

we found it again in numbers in hot spring No. 113 north of Gerlach, Nevada together with *Bufo compactilis* and *Pseudacris triseriatus*. Here the water is cool (19.2°) only slightly saline (1.0007) and moderately alkaline (pH 8.8). The salinity and hydrogen ion concentration of the water is similar in the two places (1.0015 and pH 8.5 in hot spring No. 16).

Tadpoles were collected at Paraiso Hot Springs, California in hot spring No. 143 living in water at 33.4°. At this place the water is more decidedly saline (1.0042) and it is not noticeably alkaline.

From our several observations we may say that this species occurs in water of slight alkalinity at moderate temperatures.

Pseudacris triseriatus Wied.

This frog was taken also in numbers with the preceding species, north of Gerlach, Nevada.

Rana pretiosa Baird and Girard.

On our first visit to Yellowstone Park in 1923 we secured tadpoles of this frog in a warm stream at Mary Bay near the northern shore of Yellowstone Lake. In 1930 we found adults near Tower Junction in hot spring No. 57A along the margins of the water and swimming about in water ranging from 39.2°–41.6°. The water here has a specific gravity of 1.0057 and pH of 7.0, almost exactly the same as the temperature we recorded previously for the tadpoles.

Reptilia.

Although there are several references to the occurrence of turtles in the thermal waters of Europe, we have only once encountered them in the springs we have examined, at hot spring No. 131. This is really a rather cool stream with a temperature of 28.2°, at Clear Lake Park, California. Here we took a specimen of the Californian turtle, *Clemmys marmorata* Baird & Girard.

We learned, however, through conversation with Mr. Walti, owner of the ranch on which hot spring No. 103 is located, near Cortez, Nevada, of a very interesting and surprising experience which he had had with the common Florida alligator. In 1917 two very small alligators were received and exhibited at a local bank nearby, after which they were given to Mr. Walti. Being much interested in natural history and very well informed concerning biological matters he wished to see if they might be able to find a congenial

habitat in the warm overflow from this hot spring. They were therefore given their freedom in the lower part of the stream where it enters a marshy area. For a time the alligators disappeared and had been well nigh forgotten till one cold, wintry morning in 1927, ten years later, a well-grown alligator about five feet in length was found dead in the marsh, presumably frozen to death. There seems to be no reasonable doubt that this was one of the small specimens placed there by Mr. Walti. I did not see the skin, but he showed me a photograph of the specimen. Not having seen the other animal, he supposed it to be dead, but of course there is a possibility that it may have still been alive at the time or that it may still survive.

I have absolutely no reason to doubt the accuracy of Mr. Walti's observation which furnishes an actual case of the opportunity which hot springs may offer for the extension of tropical animals into cooler regions.

ENVIRONMENTAL FACTORS.

As I have attempted to stress in previous discussions, there are several limiting factors which play a part in determining the composition of the fauna of thermal waters. Those which are most notable are the abnormally high temperature of the water, the highly variable hydrogen ion concentration and the variable salinity which is comparable to that of brackish water. It cannot be assumed that any of these act entirely independently of the others, although there can be no serious question either of the prime importance of temperature, or of its limiting action in many instances practically without reference to variations in other conditions. Hydrogen ion concentration is on the other hand only an indication of a series of factors in combination as it depends upon the chemical nature of the salts in solution, and also of the gases similarly present in solution. With reference to salts the composition of the water is quite stable, but as gases may be given off or absorbed with comparative ease and rapidity, their amounts are not at all uniform in the different parts of thermal pools or streams having the same origin. The principal reason for considering the relation of hydrogen ion concentration to the fauna is that it has actually been shown by observation to serve in many cases as an index of the suitability of waters to support animal life of various kinds. Variations in salinity as measured by the specific gravities of waters will be considered mainly because of the fact that, as I have pointed out previously, this serves as a basis for comparison of

the faunas of thermal waters, fresh-water, brackish waters and in the sea.

TEMPERATURE.

In comparison with most non-thermal springs, and with fresh water pools, ponds and streams, and also with most parts of the ocean and its estuaries, thermal springs are characterized by two temperature peculiarities. The first and most obvious is their abnormally high temperature and the second is their nearer approach to uniformity in temperature throughout the year. In tropical regions the latter is of course more or less true of all non-thermal waters, but in temperate regions, including those where the hot springs under discussion are located, seasonal variations in temperature in waters of direct meteoric origin are very great. Ranges of temperature from well below the threshold of activity (0° (32° Fahr.)) to ordinary summer temperatures in the neighborhood of 20° C (68° Fahr.) represent the normal variation for small bodies of water in these regions. There is of course no such wide variation in the temperatures of hot springs nor ordinarily in the overflows from springs during the course of the seasons, and practically all springs with considerable flow undoubtedly maintain temperatures sufficiently high to permit of activity and development throughout the winter over a part of their course. This means continued activity for most of the organisms in the springs, except in the case of insects with aërial imagines where winter activity of the aërial stage is inhibited by the low air temperatures. Just how such abnormal conditions can be adjusted to the seasonal life-cycles of certain insects is not clear and must, I think, await observations during the cold season. Certainly one of three possibilities must prevail in each case. Either the imaginal stages must be capable of hibernation, or the life cycle of the aquatic stages must extend throughout the entire winter; or the springs must be repopulated each year from nearby waters. The last possibility could not occur in many isolated hot springs which are separated by many miles of desert country from the nearest water. Some isolated springs may maintain their fauna by the overwintering of individuals in the cooler parts of extensive overflows or along the margins of shallow pools, but this does not appear fully to account for the fauna of all springs. Herein must lie the reason for the absence, so far as we have been able to determine, of any insects with aërial adult forms that are entirely restricted to hot springs, and the only

possibility for such to evolve would be through a synchronization of the life-cycle so that the aërial stage should always appear at the proper season for reproductive activity. Among animals with completely aquatic life-cycles such adjustments are not necessary, and it appears actually that the mite Thermacarus, and certain species of ostracod crustaceans are entirely restricted to hot springs. Incidentally these forms are the ones that have extended farthest upward the range of resistance to high temperatures.

On the basis of the observations made by ourselves and others it is now possible to make rather dogmatic statements concerning the extent to which animals are able to adapt themselves to high temperatures, and to establish quite accurately the upper lethal limit for animal life. This limit is quite definite for many types of animals that have been studied in this respect and so far as our experience extends and I think also that of other observers who have obtained accurate data. These all show that the upper temperature limit compatible with animal life is approximately 50° Centigrade or 122° Fahrenheit. Our highest actual record relates to the thermal mite, *Thermacarus nevadensis* which we have found living actively in water at 50.8° C., and two others to ostracod crustaceans in water at 50.0° C. In such cases there has been undoubtedly a very considerable acclimatization to heat as other species of insects and crustaceans die immediately if placed in water of that temperature. In a like manner body temperatures in the neighborhood of 40° C. (from 38°-42°) are known to cause death in numerous poecilothermic and homœothermic animals alike, while the great majority of cold-blooded animals are unable to withstand prolonged exposure to temperatures considerably lower than these. It may be said therefore in round numbers that a certain small number of animals have become in some way adapted so as to extend the upper temperature range compatible with life about 10 degrees in the centigrade scale, but that the process of adaptation is not capable of being indefinitely extended; rather it approaches with great difficulty a very definite limit. In the case of higher plants the upper limit is approximately the same as our highest record is 52.5° for the roots of a grass, *Distichlis spicata* which occurs abundantly about many of the hot springs in the regions that we have investigated.

As is well known such susceptibility to high temperatures does not obtain among the most primitive types of plant life, such as the bacteria and blue-green algæ. There are thus two types of organisms

with fundamentally different reactions toward high temperatures, the one including all groups of animals and the higher plants, and the other represented by the lowest types of plant life. I have been lead to suggest (Brues '28) that inasmuch as the only known constant structural differences between the organisms of these types is the presence of mitochondria in the one and their absence in the other, that heat susceptibility is associated directly with these cellular structures. Such a conclusion is further borne out by the observable effects of heat near the critical temperatures of 40°–50° C. upon the mitochondria in several instances. The extended observations made by us since that time all agree with my previous statements concerning lethal temperatures and as was indicated in a postscript to my former paper ('28) the one apparent disagreement among certain Protozoa has been shown to be based on dubious and probably untrustworthy data.

However, since the state of our knowledge concerning the temperature relations of certain of the lower groups of plants will scarcely permit of generalizations, it does not seem wise at this time to go further than to state that the absence of mitochondria and the generally associated imperfect differentiation of nuclear structure are characteristic of those organisms that have been able to adapt themselves to life at temperatures above 50° or thereabouts. Conversely the other series of organisms are strictly limited to the lower temperature ranges.

From our discussion of temperature it is clear that we cannot draw any distinction between the adaptations of warm and cold-blooded animals to increases in body temperature.

In a recent book by Pearse and Hall ('28) they have stated that the development of homœothermism in the higher animals has necessitated the disappearance of certain proteins that occur in some pœcilothermic animals since the body temperatures of the former are so high that these proteins would undergo heat precipitation at the normal temperatures that prevail in the tissues in warm-blooded animals. It is thus assumed that an evolutionary change has occurred before homœothermic animals could come into existence. There are, however, as we have seen, numerous types of animals in hot springs that are able to withstand temperatures well in excess of those occurring in the tissues of mammals and birds. From these types no such changes or adaptations would be necessary for the development of homœothermism so that it cannot be said that the absence of such

heat-susceptible proteins has necessarily been connected directly with the appearance of homœothermic animals. It must be admitted however that the types which are so far as we can determine most like the probable ancestors of the warm blooded animals (fishes, amphibians, reptiles) are at present not abundantly represented in hot springs. Such could not of course be expected of the reptiles as they are or have been mainly terrestrial. Of some of the early aquatic reptiles we cannot say what their relations to thermal waters may have been, but the present-day lizards and snakes are highly characteristic of hot, desert regions where abnormally high temperatures prevail. The paucity of records of turtles in hot springs, indicates clearly that these animals are not abundantly represented in thermal waters, and that as the most generally aquatic group of reptiles they show no tendency to adapt themselves to an environment where high temperatures prevail.

Certain observations by others have been published since my earlier paper ('28) was written which throw additional light on the extent of acclimatization that has occurred in some animals that are regularly or occasionally exposed to abnormally high temperatures. The first of these, relating to marine pelecypods seems clearly to give further evidence to indicate that littoral species are less susceptible to excess heat than those that live in the lower, more uniformly cooler parts of the sea.

Henderson ('29) has determined experimentally the lethal temperatures for a number of pelecypod molluscs by a gradual heating of the medium and determination of their ability to recover. He finds a wide variation in heat susceptibility among the species that he examined, ranging from 31.5°–48.5°. The more susceptible forms are in general those not normally subjected to heat, while those with limits of 40° or above include such species as *Mya arenaria* (40.6), *Mytilus edulis* (40.8), *Venus mercenaria* (45.2°) and finally *Ostræa virginiana* (48.5°) which are at times exposed to the heat of the sun. The author finds these variations clearly correlated with the habitats of the several forms. Certainly the resistance of the oyster to heat is extremely great compared with that of other animals, although continuous heat of lower degree would undoubtedly destroy them.

The effects of high temperatures on certain bark-beetles, *Dendroctonus brevicomis* Lec. have been very recently examined experimentally by Miller ('31). Miller finds in the case of larvæ of this species which develop beneath bark that death from high temperatures

is dependent to a considerable extent upon coincident dessication. Thus, in individuals removed and exposed to dry air in addition to heat a lethal temperature of from 35°–38° was determined for prolonged exposure, while from 38°–40.5° was the lethal point where evaporation was prevented by sealing up the larvæ in glass vials. At even higher temperatures of from 42°–43° recovery occurs after several hours exposure. Here it is evident that the higher limits must be regarded as indicating temperature effect unmodified by dessication which is a complicating factor in the case of terrestrial, but not of aquatic insects. Although this Dendroctonus must occasionally be subjected to excessive heat in its normal habitat beneath bark, it appears not to have developed any noticeable resistance to high temperatures.

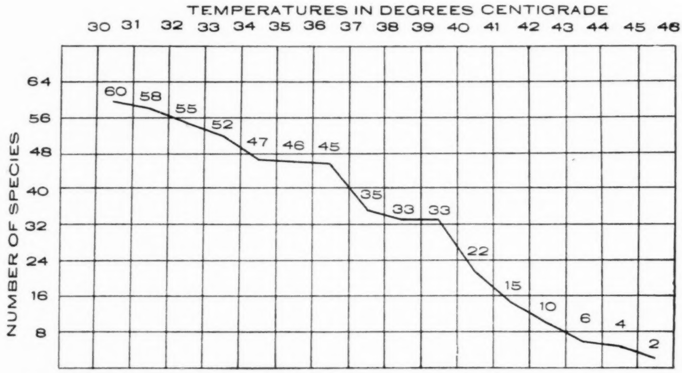

FIGURE 3. Graph illustrating the number of species of water-beetles collected in hot springs at temperatures of from 30° to 46°, showing the gradual elimination of species and reduction of the fauna as the temperature of the water increases.

Marcus ('29) states that certain Tardigrada will readily withstand temperatures of between 40° and 50° for short periods of time. He found movement to be inhibited on heating to 46°, but the animals all recovered when the medium was allowed to cool. On the other hand Heinis ('21) found that an exposure of two hours at 45° and at 47° destroyed all except certain particularly resistant species (*Macrobiotus hufelandi* and *Hypsibius oberhäuseri*). Observations by Rahm

('21) gave somewhat different results as he found that temperatures of more than 42° for a few minutes caused death.

In connection with the water-beetles which we have found living in thermal waters, I have tabulated the upper temperature limit to which each of the sixty species is known to extend. These data which are much more extensive than those formerly tabulated are combined in the accompanying graph (Fig. 3). It will be seen that there is a gradual and consistent decrease in the number of species as we pass to the higher temperatures. Those known to extend above 30° are tabulated by steps of one degree each, and the number of forms decreases gradually till only two extend into water above 45° and none above 46°. This does not form a very regular curve, but drops much more rapidly in the neighborhood of 37°, indicating that this point may be the critical temperature for a number of kinds of these beetles which belong to several related families. Otherwise the curve, which is based on approximately 300 separate records, is quite regular.

Hydrogen Ion Concentration.

In all the springs where we have collected material both in 1927 and 1930 the hydrogen ion concentration has been determined as indicated on a previous page. As would be expected from the wide range in physiographic structure of the lands adjacent to the several springs and the variety of rocks and soils through which the water passes before reaching the surface, the dissolved salts and gases in the water are highly variable both in proportions and constituents. It was found that the pH in the entire series of 149 springs where we made determinations ranges from 3.6 to 9.6 which encompasses the entire range of the indicators we had with us (see Fig. 4). At the upper and lower limits it is probable that had we been able to determine them, limits of 3.0 and 9.8 would have been found.

In spite of the fact that such determinations serve only as a crude guide in indicating similarities in composition and presumably the suitability of the several waters for particular species, the restriction of numerous species to certain ranges in pH indicates that this is actually an important factor in determining the distribution of some forms. This of course coincides with numerous observations made by others under the very different conditions that prevail in fresh-water streams, ponds, and lakes.

As may be seen from the accompanying graph (Fig. 4), there appear to be four or possibly five peaks, representing pH values of 3.6 or less

(11 springs), 7.4 (11 springs), 8.4 (14 springs), and 9.6 or above (9 springs). 54 springs, or almost exactly one-third, fall in the range of pH 7.4–8.5. Since only 17, or scarcely more than 10% of the entire number, are below pH 6.5 and only 32 or about 20% are below pH 7.0, we may class these hot springs in general as alkaline waters, remembering the notable exceptions with strongly acid waters. The springs of very low pH (3.6 to 6.2) are all either in Yellowstone Park or Mount Lassen Park, both of which are regions of notable volcanic activity and the particular springs are either ones closely associated with vents that are depositing crystalline sulphur or with certain geysers that are depositing siliceous sinter. One should

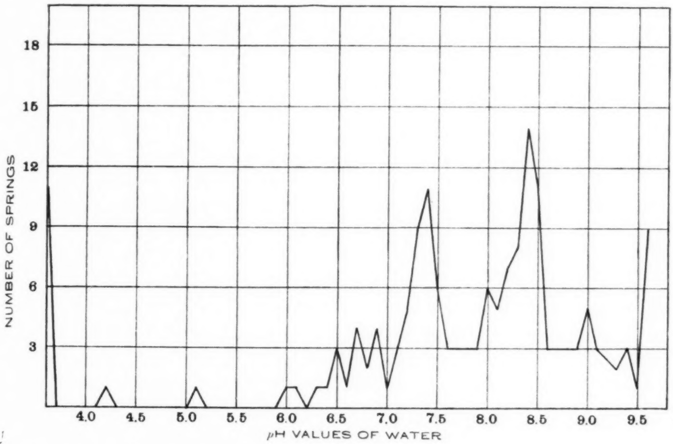

FIGURE 4. Graph showing range in hydrogen ion concentration of the waters in 149 of the thermal springs examined.

suspect sulphur dioxide in the former case. In the case of geysers it has usually been assumed that excess of alkaline carbonates is the cause of the silica in solution but it would seem that this cannot be always true.

Since our collections of water beetles include a greater number of species than any other group, I have tabulated (Fig. 5) the distribution of this series which comprises in all 61 species. As many of these are represented by numerous records (given in detail on the

preceding pages) their distribution with reference to the pH values of the waters is very well indicated. Thus combined the tendency for the number of species to decrease rapidly as the water becomes more acid or more alkaline is very evident. The most numerous records fall near pH 8 and slightly above, which represents the most favorable range for members of this group in general. As the number of records that we have accumulated for other groups are much more meagre, I have not attempted to tabulate them at the present time.

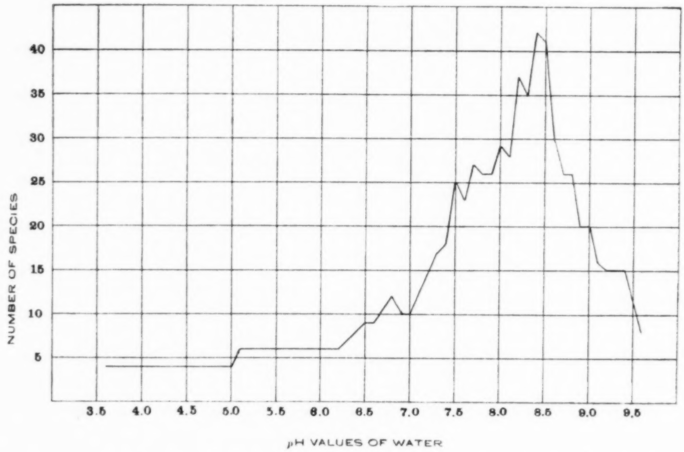

FIGURE 5. Graph showing range of 61 species of water-beetles in hot springs, with reference to the hydrogen ion concentration of the water. Each species is included in the graph over the complete range of pH values at which it has been collected.

The hydrogen ion concentration of the other waters from which animals might migrate into hot springs in the region where we have done our work is a matter which should be considered here, but I have been able to secure very few data relating to this. Shelford ('25) has published a number of pH determinations of waters in inland and coastal drainages in the west which seem to indicate generally a higher pH for the waters of the western plains and Great Basin. The averages of his tables are as follows:

Puget Sound and Columbia River Basins	7.3
Salt Lake and Colorado and Rio Grande Basins	7.8
Mississippi and Great Lake Drainage Basins	7.4

These differences are not very great, but nevertheless noticeable, although of course there are none of the great extremes that are encountered in hot springs and alkali ponds scattered through the west. Omitting the low records of 3.6 or below, we find that the mean of the springs we studied (pH 8.0) is not greatly in excess of the figures given by Shelford for non-thermal waters in the same general region. The majority of the springs are therefore similar in pH values to the waters from which migration from cooler water must have occurred while the more acid springs, where there is a great difference in pH from meteoric waters, have acquired a much more limited fauna.

An interesting comparison with the data just given is afforded by a series of observations on the distribution of fresh-water Copepoda with reference to pH that has been published by Lowndes ('28). These relate mainly to England but include also collections from Spitzbergen and Lake Lucerne, so the list may be considered as representative of conditions over an extended area. Lowndes finds that the pH values of the waters ranged from 3.0 to 9.8 and that none of the species of copepods were obtained over the entire range although *Cyclops langvidus* Sars (3.0–7.2) and *Cyclops vulgaris* Koch (4.6–9.8) show very wide ranges. In breeding experiments he found that the former species would develop through the widest range of pH, water of high pH being toxic only when calcium and magnesium salts were present to any great extent. He concludes that variation in hydrogen ion concentration can have no direct influence on this species and that probably its influence on other species is small.

I have plotted as a graph which is reproduced below (Fig. 6) the data given by Lowndes in his list of species and it appears from the standpoint of diversity that the fauna of the different waters is clearly correlated with the pH, showing a maximum (22 to 33 species) from pH 5.4 to 8.2 and decreasing very rapidly both above and below this range, particularly at the points of pH 4.5 and pH 8.7. Criticism of such a treatment may of course be made on the basis that there are more ponds falling in the middle ranges and consequently greater opportunities for obtaining longer lists for them. As many of the species (more than one-half) were common and represented by extensive records and as will be noticed, especially in the waters with

high pH values, that a few species extend far beyond the median ranges, it is evident that pH values clearly indicate conditions in the medium which restrict the distribution of these copepods.

Schumann (1928) has shown that in certain waters Gammarid crustaceans cannot develop in water having an acid reaction (between pH 5.6 and 6.5) although the optimum appears to be between 7.2 and 7.8. In the case of these animals a considerable calcium content of at least 13 parts per million of $CaCo_3$ is necessary for their growth and development.

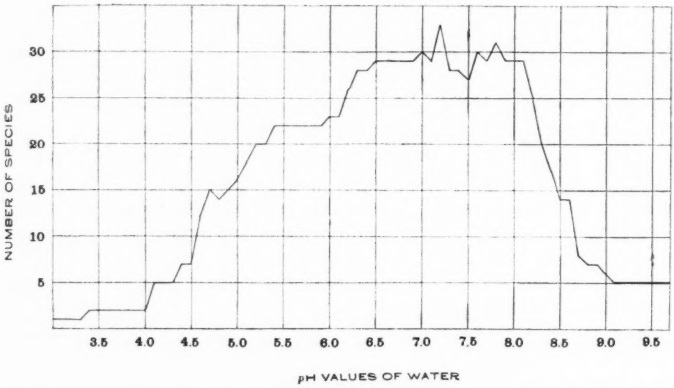

FIGURE 6. Graph showing range of European copepod crustaceans with reference to the hydrogen ion concentration of the water. Compiled from data published by Lowndes ('28).

The relation of hydrogen ion concentration to the development of mosquito larvæ, particularly those of malarial mosquitoes has engaged the attention of several entomologists. The European *Anopheles maculipennis* shows a definite range of tolerance with reference to the pH of the water, at least in peaty soils, as has been demonstrated by Sébenzow and Adowa ('29). They found that the first instar larvæ cannot withstand a pH of less than 5.0, although the third stage larvæ are able to tolerate water at pH 4.3, which point is the limit of tolerance for the developmental stages of this mosquito. Biriukov ('28) found that Anopheles in Russia did not develop in water of pH below 7.2, nor above 7.6 but he does not say what ranges he has investigated.

Similarly Senior-White ('26) has found several species of Anopheles in India extending from pH 5.8 to pH 8.6 which is rather toward the middle of the scale of the values that are ordinarily encountered in waters. The latter author has also made many observations on a variety of other mosquitoes which are embodied in the same publication. As his data are very similar to those of Lowndes for copepod crustaceans, I have plotted them in a similar way for comparison (Fig. 7). One sees in the graph that most of the 46 species crowd toward the range of pH 6.0–8.8, but with a much more pronounced

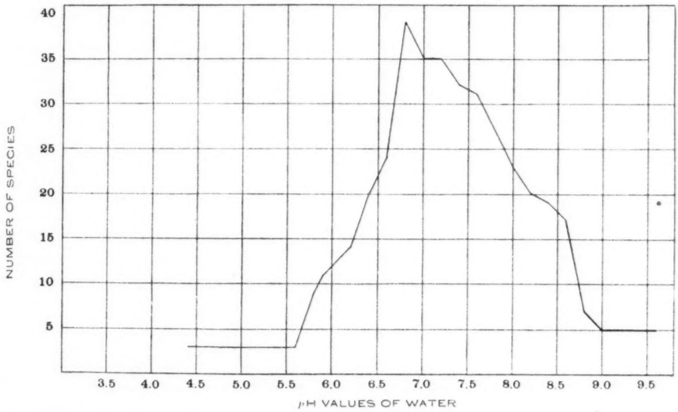

FIGURE 7. Graph showing range of 46 species of Indian mosquitoes with reference to the hydrogen ion concentration of the water. Compiled from data published by Senior-White ('26).

peak at pH 6.6. One species *Stegomyia albopicta* extends over the entire range from pH 4.4 to 9.6. Here it is evident the peak of abundance is well below that shown for the beetles given on a previous page.

Among molluscs the tolerance of the snail, *Lymnæa truncatula* for water of varying hydrogen ion concentration has been determined by Walton and Wright ('26) who found that it ranged between pH 6.0 and 8.6 while another species of the same genus, *L. peregra* can withstand a somewhat wider range from pH 5.8 to 8.8.

Jewell and Brown ('29) who have studied extensively the fauna of

certain bog lakes in northern Michigan come to the conclusion that pH is rarely a limiting factor in the occurrence of fresh-water fish in natural waters as they found fish in waters ranging from pH 4.4 to pH 10.0, no single species extending over the entire range, however. With molluscs they found no species in very acid water as the range for them was from pH 5.7 upwards. The lower figure approximates the point at which the deposition of lime shells would theoretically be inhibited.

Similarly with fishes, Schäperclaus ('27) finds from observations in Germany that the lower limit of tolerance of fresh-water fishes is sharply limited in the acid range of pH 4.8.

From the data just presented we are certainly not justified in concluding that the reaction of the medium as measured by its pH is without influence in determining the composition of its fauna. Whether this is a direct influence or whether it may depend upon the presence of suitable food cannot be stated, but the fact remains that the pH value in particular cases is one of the indices of the suitability of the habitat.

Salinity.

Of undoubtedly lesser importance than temperature in determining the composition of the thermal fauna are differences in the salinity of the water in hot springs. Since water becomes a better solvent of nearly all salts as its temperature is raised we must expect on the average to find a greater amount of substances in solution in hot springs than in other natural waters, excluding of course the sea and certain smaller bodies of water without outlets in which the concentration of dissolved substances is continually increased through evaporation. In the region where the hot springs we have investigated are located there are numerous examples of this condition such as Great Salt Lake and Mono Lake which show much higher salinities than the ocean. There are even others where the dissolved salts are concentrated almost to the point of crystallization or where solution occurs only with the advent of periodic or occasional rains. Even Salt Lake and Mono Lake support a fauna and flora of meager extent while the many less strongly saline waters of the region are well populated by organisms adapted to life under the conditions that prevail so that there are numerous forms present elsewhere in the region which are living in waters of salinities comparable with those encountered in the thermal waters. That the salinity of the hot springs has been a really important factor in determining their fauna

is shown indirectly, but I think quite conclusively, by the types of insects and other invertebrates found there.

As might be expected there is great diversity in the salinities of the 154 hot springs that I have reported upon. On the basis of specific gravities when these are reduced to a uniform temperature of 15° C. we find that the majority fall between 1.0010 and 1.0070 (Fig. 8) with a very clearly defined peak in the neighborhood of 1.0040. Practically none fail to show an appreciable amount of salts in solution and a few not included in the figure show very excessive amounts (1.0146–1.1181) due to high concentrations of NaCl and other salts. Only at the highest concentration of 1.1181 in hot spring No. 151 did we fail to find macroscopic forms of animal life.

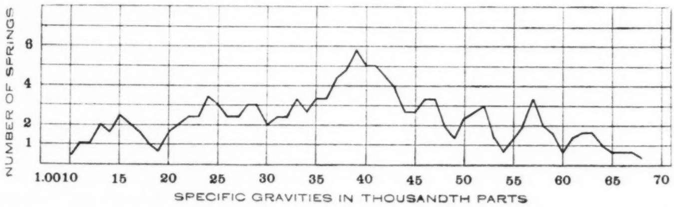

FIGURE 8. Graph showing range in specific gravity of the waters in 135 of the thermal springs examined. A few other springs falling beyond this range have been omitted.

In my previous account of the hot springs fauna I have called attention to the fact that the general constitution of this fauna with reference to groups, genera and species runs closely parallel to that of brackish water. From this I have drawn the obvious conclusion that those types which have been able to migrate from fresh water into brackish water without encountering insurmountable difficulties have been likewise able successfully to invade the generally strongly saline waters of thermal springs. If one views the series of types concerned it is evident that they are those which are able for some reason to live and reproduce readily water of greater salinity than that of the fresh-water medium from which they have come, since the hot springs fauna comprises almost entirely fresh-water animal types.

The physiological basis for this difference between types of animals must be dependent upon their actual ability to adjust themselves

to the changed osmotic pressure which they encounter in the hot springs or saline habitat. Since the mechanism or mechanisms for osmotic control in animals whereby their body fluids are kept at uniform, or sometimes variable, concentrations with reference to the external medium seem never to have been clearly demonstrated, it would be idle to speculate further in the present connection. In fact, Schlieper ('30) in an elaborate consideration of this question comes to the conclusion that all aquatic animals have mechanisms for active osmotic control, that some (e. g. the crab, *Carcinus mœnas*) may consistently maintain a higher, or even lower, molecular concentration than that of the external medium. Undoubtedly, no simple explanation will finally be offered for the hot springs fauna as a whole, but it is difficult to believe that there are not differences inherent in certain specific types of animals in this respect, in view of the similarities between the thermal and brackish water fauna.

In at least one group of animals, the fishes, investigations by Smith, summarized in a recent paper ('32) and Keys ('31) have shown that in fishes the chlorides of sodium and potassium are excreted by the gills in solution hypertonic both to the blood and to sea water, thus enabling these animals to prevent the accumulation of these salts in the body fluids and to secrete a hypotonic urine. In marine invertebrates the body fluids are usually isotonic to sea water, although those of fresh water forms are strongly hypertonic to the external medium. Whatever the mechanism of osmotic control among these varied animals may be, it cannot always be like that in the fishes as organs similar to the gills of fishes are not uniformly present.

ADJUSTMENTS OF THERMOPHILOUS ANIMALS.

Investigation of the fauna of thermal springs shows conclusively that its components have been selected with reference to their ability to live and reproduce at temperatures which are higher than those which most animals can endure. This adaptation to high temperatures extends however over only a narrow range of about 5° to 20° Centigrade, as the animals live at temperatures of 40° to 50° C. instead of 30° to 40° which is the upper limit of existence for the majority of terrestrial and aquatic animals alike, including both pœcilothermic and homœothermic types. Such a condition of greater resistance to heat may have arisen either by a selection of forms naturally resistant, whereby such forms have found the environment of hot springs not detrimental to their welfare, or it may have come

about through actual changes in the constitution of the animals whereby they have become more resistant to heat on account of actual changes in their protoplasmic composition or metabolic requirements. A third possibility that they represent remnants of a promordial fauna which have always lived at high temperatures may be dismissed as I have already indicated ('28) in the case of animals and the higher plants, although it may be true of some primitive types of plant life.

It is difficult to make any positive statement as to whether the fauna of thermal springs is wholly or in part made up of naturally resistant forms. Many observations on diverse animals show that the inhabitants of cooler environments are not all equally susceptible to heat when this is tested experimentally, some showing the ability to withstand temperatures similar to those met by the species that live in hot springs. Some such forms have probably become a part of the thermal fauna. On the other hand species in several groups show a great lack of heat susceptibility when compared with related forms from cooler environments and in such cases actual physiological adaptation to heat must have occurred. So far as known, however, in animals adaptation to heat never occurs beyond the critical point of 50°–51° centigrade.

Adjustment to the higher osmotic pressure of saline waters is of course not restricted to members of the thermal water fauna as the same adjustment is necessary for all fresh-water animals that invade brackish waters of the sea. That salinity is a factor in determining the composition of the thermal fauna has been shown by the similarities we have pointed out between it and the estuarine faunas.

Finally, in company with all non-marine faunas, the thermal fauna appears clearly to be selected to some extent with reference to the extremely variable hydrogen ion concentration of thermal waters.

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